Jim Glanville
Virginia Western Community College
Roanoke, 24015
and **Eric Rau**
FMC Corporation, P.O. Box 8
Princeton, New Jersey 08540

Soda Ash Manufacture—An Example of What?

Textbook authors use the Solvay process of soda ash manufacture to illustrate a variety of chemical principles. However, in the last decade, shifting economic conditions and the need for pollution abatement measures have led to dramatic changes in the industry. The causes and effects of these changes are highly instructive.

Historical Background

Sodium carbonate (soda ash) is one of the highest volume industrial chemicals manufactured in the United States (*1*). The first Solvay process plant was built in 1884 by Rowland Hazard at Syracuse, N.Y., and two more were built in 1895 (*2*). Solvay process plants continued to be constructed until 1935, when ten plants were in operation. High capital and labor expenditures have prevented new construction since then (*3*).

Development of Natural Soda Ash

The major factor causing the decline of the Solvay process is the development of natural evaporite deposits in Wyoming and California. Trona (sodium sesquicarbonate, $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) occurs naturally in vast quantities. The Green River, Wyo., deposit covers 900 square miles, and may contain as much as 17 billion tons of trona (*4*).

Commercial production of soda ash from trona began in 1948, and has accelerated since then, whereas Solvay process production has remained constant (Fig. 1). All three of the manufacturers located at Green River have announced plans to again substantially increase their production capacities. By the middle of 1973 the United States production of natural soda ash will outstrip the Solvay production (*5*).

Soda ash is recovered in pure form from trona by dissolving the ore, crystallizing $Na_2CO_3 \cdot H_2O$ or $Na_2CO_3 \cdot NaHCO_3 \cdot H_2O$ from a purified solution and then calcining. The only wastes are the insoluble materials filtered from the solution. These wastes can be used for land fill and cause no ecological problems. Before 1958, natural ash was only marketed west of the Mississippi, but the use of large-capacity freight cars has made possible nationwide competition with the synthetic material.

Pollution Control at Solvay Plants

The net reaction for the Solvay process may be represented by the equation

$$2NaCl + CaCO_3 = Na_2CO_3 + CaCl_2$$

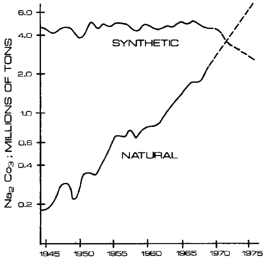
and the process has been estimated to operate at a yield of 75% (*6*). This means that for each 100 tons of product about 170 tons of combined calcium chloride and process wastes are generated. Unfortunately, the by-product calcium chloride presents a massive disposal problem. Very little of it is recovered for use (*7*), and it is usually dumped or stored in holding ponds. Further recovery of the calcium chloride is pointless, since the amount of by-product from the Solvay plants far exceeds the annual demand.

In 1971, the closing of two Solvay process soda ash plants was announced—at Barberton, Ohio and Saltville, Va. (*8, 9*). In both cases the companies involved cited difficulties involved in meeting standards set for discharge of effluents, as well as economic conditions. There has been some controversy as to the relative importance of the economic factors compared to the tightening of effluent standards (*10, 11*), but it is clear that both of these forces were operative to some degree in these two plant closings.

Thus, with the exception of plants located sufficiently close to the ocean to economically dispose of saline wastes to sea, all of the Solvay process plants will find it necessary to spend more money on abatement procedure to control effluent quality. This will have the effect of making them less competitive, and contribute to their decline. One observer of the chemical industry has gone as far as to predict that most Solvay process plants in the United States and Western Europe will be shut down in 1980–85 (*12*).

Competition from Sodium Hydroxide

As one of the two high-volume inexpensive alkalies, soda ash faces a natural competition for many uses from sodium hydroxide. This is particularly true in glass making—soda ash's largest single market. The production of sodium hydroxide, however, is to a large extent influenced



Trends in U.S. soda ash production (adapted from reference (3)).

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by the demand for chlorine, since chlorine and sodium hydroxide are co-products of the electrolysis of salt.

The market for chlorine has grown very rapidly, primarily as a result of the strong demand for chlorine in the manufacture of polyvinyl plastics. However, the growth of these plastics, while steadily increasing, still undergoes wide swings in demand. When chlorine is in large demand, sodium hydroxide is produced in excess and similarly the reverse is true. Since there is no way to store either chlorine or sodium hydroxide, the excess must be sold at whatever the market will pay. At present, because of decreased demand in the auto industry, chlorine is long, while the caustic supply is very tight.

If a glut of sodium hydroxide occurs, then soda ash may be produced by reaction of the sodium hydroxide with carbon dioxide.

$$2NaOH + CO_2 = Na_2CO_3 + H_2O$$

A number of freshman texts refer to this procedure as the "Electrolytic Process" for the manufacture of sodium carbonate, but its use in the United States was abandoned in 1969 when Dow closed its Freeport plant. European producers are considering using this approach in conjunction with salt electrolysis. Excess caustic would be reacted with CO_2 in large spray towers.

Summary and Conclusions

The use of the Solvay process to exemplify certain principles in freshman courses can be extended into the areas of chemical economics and environmental pollution. The Solvay process is an example of a process that is facing tough competition from a newer and cheaper source (natural ash) and suffering from heavy additional costs due to the need to provide adequate control to its effluent.

These aspects of the Solvay process can be introduced into freshman courses to give timely and relevant examples of problems faced by industrial chemists and their employers.

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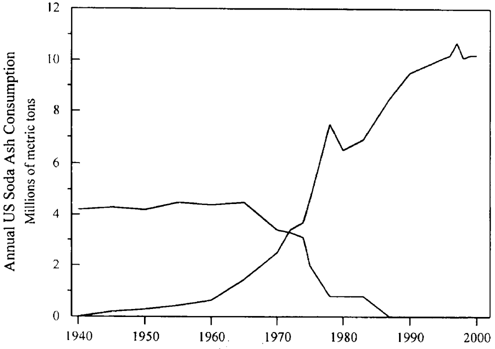
US Soda Ash

Synthetic versus Natural—The Rest of the Story



Falling line, synthetic, Solvay, soda ash
Rising line, natural soda ash

All data converted to 1000's of metric tons.

Sources:

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Jim Glanville

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