Sodium Carbonate Manufacturing Report

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1. Introduction

Sodium carbonate (Na, CO_2) is used by many different industries as a raw material, and about one million tonnes is produced each year in the UK all of it by the Brunner. Mond Company in Northwich, Cheshire. Also produced in smaller quantities is sodium hydrogencarbonate (NaHCO3) as well as calcium chloride ($CaCl_2$)- a by-product, a little of which can be sold.

Industrially, sodium carbonate is usually referred to as 'soda ash' and is produced and sold in two grades:

- ✓ light ash - a fine powder; and
- ✓ heavy ash - which has a bigger particle size and is more dense, making it less bulky to transport.

Sodium hydrogencarbonate is used in:

- ✓ water treatment;
- ✓ as an additive in food and drinks-eg baking powder;
- ✓ for blowing foams such as expanded polystyrene;
- ✓ in pharmaceutical products as an antacid;
- ✓ in personal care products such as toothpaste; and
- ✓ as an additive in animal feeds.

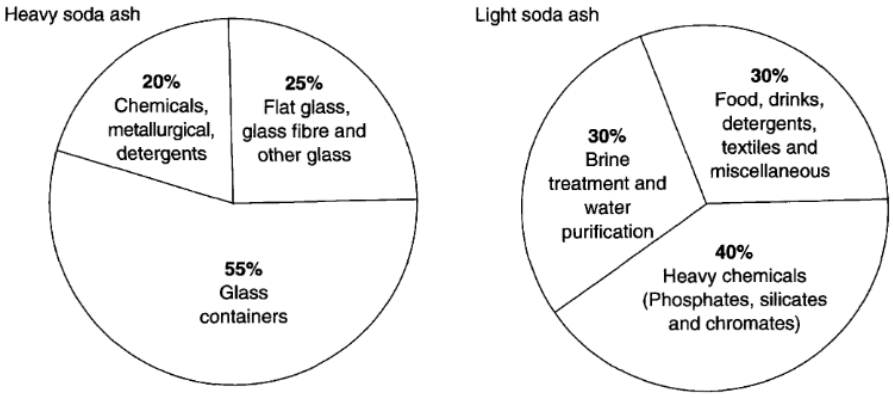


Figure gives an approximate breakdown of the uses of light ash and heavy ash but these are subject to change depending on a number of social and economic factors. For example, in a recession, fewer cars and houses are built, which reduces the demand for glass. Importing of alcoholic drinks from the continent due to more liberal customs regulations has led to a decrease in the number of glass bottles made in the UK and thus a drop in demand for heavy ash.

2. The Solvay process

This process has been used for making sodium carbonate and sodium hydrogencarbonate since the late 19th century when it began to replace the Leblanc process. No more effective process has been found. The Solvay process uses salt (sodium chloride) to provide the sodium ions and limestone (calcium carbonate) for the carbonate ions in the sodium carbonate.

Salt and limestone are cheap and plentiful raw materials. Salt is found in underground deposits in Cheshire. It is extracted by solution mining as brine which is then pumped to the site and treated to precipitate out calcium and magnesium ions. The calcium carbonate is quarried as limestone near Buxton in Derbyshire and arrives on site by rail.

The reaction below seems to be the obvious way to prepare sodium carbonate from sodium chloride and calcium carbonate.

2NaCl(aq) + CaCO, (s) Na, CO, (aq) + CaCl, (aq)

The key reaction is that between sodium chloride solution and carbon dioxide in the presence of ammonia. This is a reversible reaction forming ammonium chloride and sodium hydrogencarbonate. It occurs in 25 metre-high Solvay towers where a downward flow of ammonia dissolved in brine meets an upward flow of carbon dioxide.

$NaCl(aq) + NH(aq) + H_2O(l) + CO_2(g)$

Energy for the overall process is provided by burning coke.

C(s)+O(g) CO, (g)

The heat generated by this reaction is used to decompose the calcium carbonate to provide the carbon dioxide.

CaCO3(s) → CaO(s) + CO2(g)

Returning to the key reaction.

$NaCl(aq) + NH, (aq) + H_2O(l) + CO_2(g)NH Cl(aq) + NaHCO, (s)$

Sodium hydrogencarbonate is much less soluble than ammonium chloride at low temperature and crystallises out. The equilibrium in the Solvay tower reaction thus moves to the right. The reaction is exothermic (ΔH = -79 kJ mol), so the tower is cooled to keep the temperature at its base down to about 25 °C. The sodium hydrogencarbonate is filtered out and heated to form sodium carbonate ('light ash").

2NaHCO3(s) Na, CO, (s) + CO2(g) + H_2Ol(g)

The carbon dioxide is recycled.

The calcium oxide from the decomposition of the limestone is slaked with water to form calcium hydroxid.

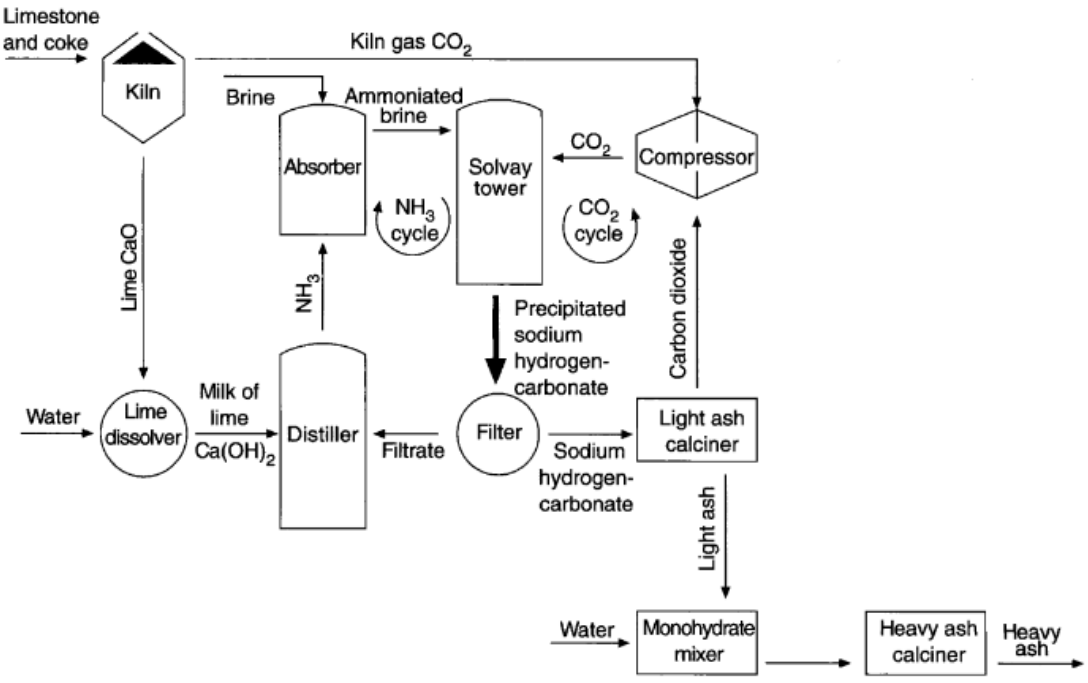
CaOfs) + H_2O(l) → Ca(OH), (s)

This is used to regenerate the ammonia in the distiller.

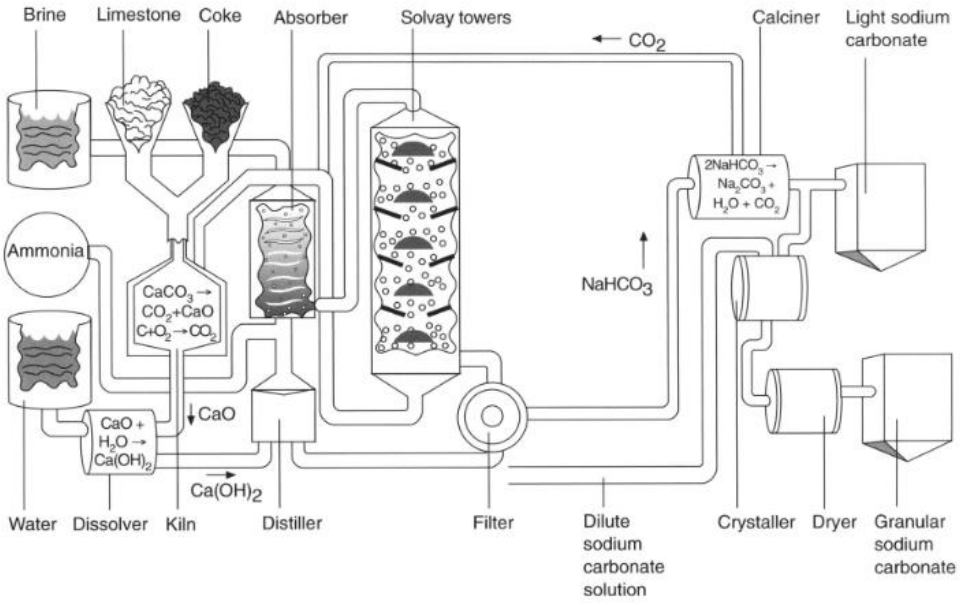
Ca(OH),(5)+2NHCl(aq) → CaCl(aq) + 2NH, (aq) + 2H_2O)

The ammonia is recycled.

The overall process is shown in a simplified form in Figure 2 and more pictorially in Figure 3. It operates as two cycles, an ammonia cycle and a carbon dioxide cycle. In theory, no ammonia is used up; it is all recycled. In practice, a little is required to make un losses.



The Solvay process manufactures three different products - light sodium carbonate (light ash), granular sodium carbonate (heavy ash) and refined sodium hydrogencarbonate.



Light sodium carbonate (light ash)

This is made by taking filtered sodium hydrogencarbonate and heating it. This drives off water and carbon dioxide, which can be recycled. The product is a very fine white powder.

Granular sodium carbonate (heavy ash)

Light sodium carbonate is made into a slurry with water, to form sodium carbonate monohydrate. This is then heated to produce the anhydrous form as much larger crystals. These crystals have a particle size similar to that of sand so that the two make a homogeneous mixture which is important for glass making the major use for heavy ash.

Refined sodium hydrogencarbonate

Crude sodium hydrogencarbonate is filtered and decarbonated and dehydrated by heating to give sodium carbonate. This is dissolved in water and the resulting solution is filtered to remove impurities, Highly pure sodium hydrogencarbonate crystals are formed by reacting the filtered solution with carbon dioxide. These crystals are then centrifuged and dried in a carbon dioxide atmosphere. The product is one of the purest industrial chemicals, and can be added to foods and pharmaceutical products.

The main by-product of the Solvay process is calcium chloride. A little of this can be sold for use in refrigeration, curing concrete and as a suspension in oil drilling. The bulk of calcium chloride is disposed.