ChE 308
Lecture 4

Chlor-Alkali Industries: Caustic soda, Chlorine, **Soda Ash**(cont'd)

Sodium Carbonate Production

SOLVAY TECHNIQUE

- **The Overall reaction:**

$2\ NaCl + CaCO_3 = CaCl_2 + Na_2CO_3$

Besides Soda the Solvay Technique also causes $CaCl_2$ as a by-product.

- **General bases of the production process:**

For the manufacture of 1 ton of Soda Ash by means of SOLVAY TECHNIQUE 1.5 ton salt, approximately 80 m^3 water, 1.2 ton limestone and 0.1-0.5 ton coke are required.

Sodium Carbonate Production cont'd

SOLVAY TECHNIQUE cont'd

The total process can be divided into the following reaction steps:

1. **Brine Cleaning**
2. **Manufacture of the product**
3. **Lime Milk preparation**
4. **NH_3 recovery**

Sodium Carbonate Production cont'd

1. Brine Cleaning

•Precipitation of Magnesium Hydroxide and Calcium Carbonate by the addition of lime milk and soda solution into the brine:

$$Mg^{2+} + Ca(OH)_2 = Mg(OH)_2 + Ca^{2+}$$

$$Ca^{2+} + Na_2CO_3 = CaCO_3 + 2\ Na^+$$

2. Manufacture of the product

• Precipitation of the relatively heavy-soluble bicarbonate (NaHCO3) by the addition of carbonic acid into a salt solution saturated with ammonia:

$$NaCl + H_2O + NH_3 + CO_2 = NH_4Cl + NaHCO_3$$

•Thermo decomposition of the bicarbonate:

$$2\ NaHCO3 = CO_2 + H_2O + Na_2CO_3$$

Sodium Carbonate Production cont'd

3. Lime Milk preparation

- Manufacture of caustic lime:

$$CaCO_3 = CaO + CO_2$$

- Manufacture of lime milk:

$$CaO + H_2O = Ca(OH)_2$$

4. NH_3 recovery

- Recovery of the ammonia by distillation of ammonium chloride containing mother liquor with lime milk:

$$2\,NH_4Cl + Ca(OH)_2 = 2\,NH_3 + 2\,H_2O + CaCl_2$$

- The calcinations also lead to the following parallel reactions, which generate ammonia as well as sodium chloride:

$$NH_4CO_3 = NH_3 + CO_2 + H_2O$$

$$NaHCO_3 + NH_4Cl = NH_3 + CO_2 + H_2O + NaCl$$

In this side reaction, soda is polluted with sodium chloride

Sodium Carbonate Production cont'd

LeBlanc Process

- The LeBlanc process was a batch process in which sodium chloride was subjected to a series of treatments ,eventually producing sodium carbonate.
- In the first step , the sodium chloride was heated with sulfuric acid to produce **sodium sulfate (salt cake)** and **hydrochloric acid gas** according to the chemical reaction:

$$2\ NaCl + H_2SO_4 = Na_2SO_4 + 2\ HCl$$

- LeBlanc's contribution was the second step , in which the salt cake was mixed with **crushed limestone (calcium carbonate**) and coal and fired.
- In the ensuing chemical reaction, the coal (carbon) was oxidized to **carbon dioxide**, reducing the **sulfate** to **sulfide** and leaving behind a solid mixture of sodium carbonate and calcium sulfide (black ash).

$$Na_2SO_4 + CaCO_3 + 2C = Na_2CO_3 + CaS + 2\ CO_2$$

Sodium Carbonate Production cont'd

LeBlanc Process cont'd

- Because sodium carbonate is soluble in water, but neither calcium carbonate nor calcium sulfide is , the soda ash was then separated from the black ash by washing it with water.

- The wash water was then evaporated to yield solid sodium carbonate. This extraction process was termed lixiviation.

Sodium Carbonate Production cont'd

Uses of sodium carbonate include:

- manufacture of soap, glass, ceramics, paper, sodium hydroxide and sodium hydrogen carbonate (carb. soda)
- petroleum refining
- water softener
- cleaner and degreaser in washing compounds
- removing sulfur dioxide from waste gases in power stations.