

## **KE-107.4300 Process design I**

15.12.2009 9-12

You may answer in English, Finnish or Swedish.

*Theory part (no literature may be used) 9-10*

Answer shortly:

1. Explain shortly:
  - a) Atex
  - b) Magnetic pump
2. Heat transfer alternatives for reactors
3. Storages for gases and liquids
4. General considerations in making process layout

*Design part see next page*

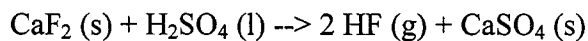
*Physical properties are given in 'Process design manual'.*

## KE-107.4300 PROCESS DESIGN I DESIGN PART

*(lecture notes and other literature may be used, except solved exercises) 10-12*

### The Manufacture of Hydrogen Fluoride -A Process Design Case Study

Hydrogen fluoride is manufactured in a continuous process from fluorspar, a solid found abundantly in the earth by the following reaction:

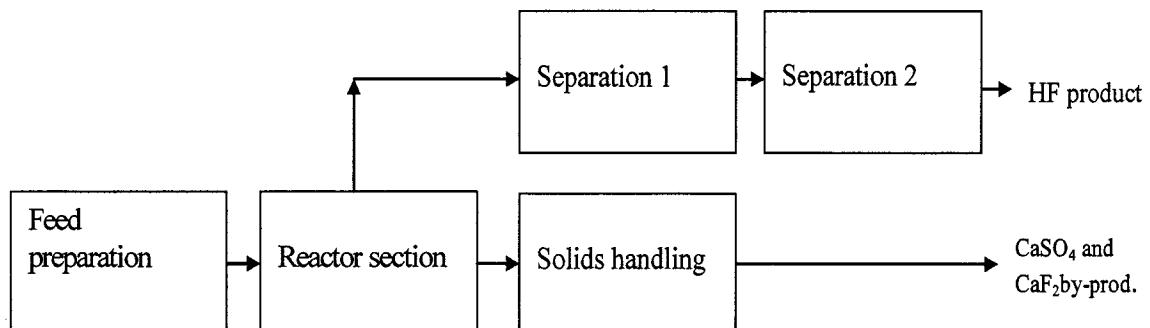


Conversion of  $\text{CaF}_2$  is 99%.  $\text{H}_2\text{SO}_4$  100 wt-% is available 50 000 t/a.  
Small part of sulfuric acid decomposes to water and sulfur trioxide in reactor.  
Some nitrogen enters the reactor with fluorspar.

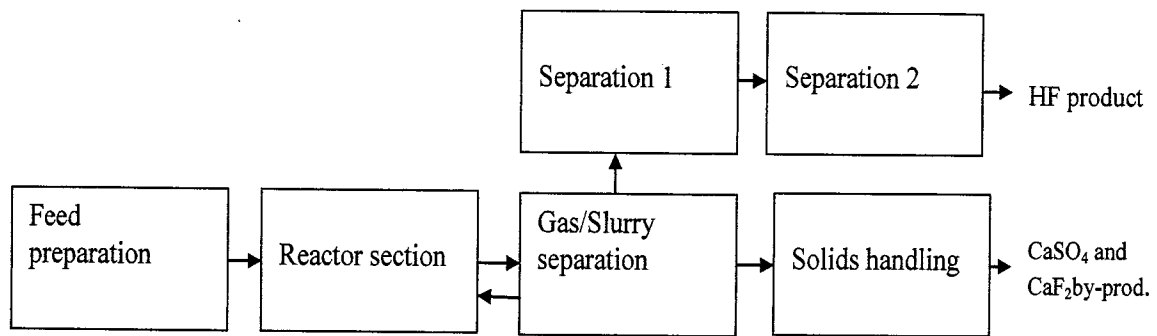
Three different process alternatives based on this chemistry are found in the literature:

- Solid-Gas Process:** Reaction carried out in an expensive fluidized bed reactor. It uses an extra exothermic reaction for making of  $\text{H}_2\text{SO}_4$  from  $\text{SO}_3$  and steam. Operates at 10 bar. This reaction is carried out at 400 °C.
- Solid Process:** Incorporates a relatively simple reactor. Operates at 5 bar. This reaction is carried out at 300 °C.
- Slurry Process:** This process is carried out in a relatively expensive multiphase reactor with a flammable organic diluent which is recycled. No water is used. Operates at 20 bar and 200 °C.

The block flow diagram for Solid-Gas and Solid processes:



The block flow diagram for Slurry process:



Feed /product and other specifications:

Feedstock/product	Specification	BP (°C)	Costs (€/t)
Hydrogen Fluoride	HF (as pure as possible)	19.5	1300
Sulfuric acid	H <sub>2</sub> SO <sub>4</sub> 100 %	337	80
Fluorspar	CaF <sub>2</sub> 98% and portion of CaCO <sub>3</sub> , Si; SiO <sub>2</sub>		200
Sulfur Trioxide	SO <sub>3</sub> 100%	45	
CaSO <sub>4</sub>	Gypsum		30
Utilities available	2 bar and 10 bar steam		
Operating hours	8000 h/a		

Assume HF has same corrosion behavior as hydrofluoric acid.

*Answer the following questions:*

1. Analyze the reaction, how much HF (100%) can be produced?
2. Calculate the heat of reaction of the main reaction at 25 °C.
3. See if you can make money, calculate the economic potential.
4. Compare the process alternatives based on main criteria (exclude health criteria for simplicity)
5. Draw and propose gas separation flow diagram for the best alternative.
6. Show controls (pressure, flow, level and composition) of a separation system.
7. What are the construction materials you propose for the gas separation section
8. What is the diameter of the gas outlet line after reactor (in the reactor temperature and pressure).

Each task: 1p; Seminar & exercise attendance 3p; Total: 15p