Kem-107.4300 Process design I
7.1.2009 13-16

You may answer in English, Finnish or Swedish.

Theory part (no literature may be used) 13-14

Answer shortly:
1. a) steam trap
   b) Atex
2. Plastics as construction materials
3. How relief systems are sized for maximum load
4. Separators for vapour/liquid and liquid/liquid mixtures
5. Design considerations for acid storages -sai

Design part see next page

Design part (lecture notes and other literature may be used, except solved exercises) 14-16

Phosphoric acid is manufactured in a continuous process (8000 h/a) by dissolving finely ground apatite mineral into sulphuric acid:

Apatite mineral

$Ca_{10}(PO_4)_6F_2$ (s) + 20 H_2O(l) + 10 H_2SO_4(aq) -> 6 H_3PO_4(aq) + 10 $CaSO_4 \cdot 2H_2O$ (s) + 2HF(g)

Heat of reaction is -160 kJ/mol phosphoric acid

Two phenomena are taking place:
1) dissolving of apatite particles in sulphuric acid. Total dissolving takes place in 0.5 h.
2) crystallization of gypsum as $CaSO_4 \cdot 2H_2O$ takes 3 hours .
The gypsum solubility is not dependant on the temperature.

Hydrogen fluoride gas leaves the process, since HF is not much soluble in acids. HF cannot however be emitted into atmosphere but has to be separated.
In the end gypsum crystals are separated from the phosphoric acid product.

Aims of the continuous process are:
i) Avoid getting undissolved apatite into gypsum product.
ii) The gypsum should be precipitated as $CaSO_4 \cdot 2H_20$, not as $CaSO_4 \cdot 1/2H_20$, which fouls surfaces.

Raw materials:
30 wt % sulphuric acid is available 100 000 t/a.
Very finely ground apatite is available enough.

151,93 °C

Utilities available:
Cooling water at temperature 20 °C and 500 kPa pressure.
Saturated steam at 600 kPa. 158 °C
Electricity and instrument air.

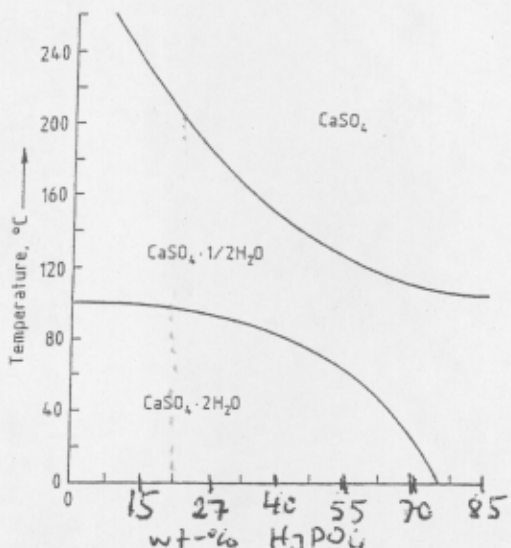

Figure 10. Stability range of calcium sulfate and its hydrates in phosphoric acid

Questions:
1. How much phosphoric acid can be produced?
2: What is the phosphoric acid concentration?
3. What kind of reactor type you propose and why?
4. What operation temperature you propose for the process and why?
5. Calculate the reactor volume.
6. What type of heat exchange system you propose for the reactor? Calculate the area (assuming the feeds are in reaction temperature).
7. Draw the flowsheet of the process you propose with controls (but without material balance)

USE PROCESS DESIGN MANUAL FOR PHYSICAL PROPERTIES ETC.
Apatite molecular weight is 1008 g/mol. Apatite solid density is about same as calcium phosphate.

International Labour Organization

International Occupational Safety and Health Information Centre (CIS)

[List of Chemicals] [Risk Notes] [Risk Phrases] [Safety Phrases] [Danger Symbols]

HYDROGEN FLUORIDE

ICSC: 0283

April 2000

Hydrofluoric acid, anhydrous

CAS No: 7664-39-3
RTECS No: MW7875000
UN No: 1052
EC No: 009-002-00-6

(cylinder)
HF
Molecular mass: 20.0

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRI
FIRE	Not combustible. Many reactions may cause fire or explosion.		In case of fire in the use appropriate extir media.
EXPLOSION			In case of fire: keep by spraying with wat direct contact with w fire from a sheltered
EXPOSURE		AVOID ALL CONTACT!	IN ALL CASES CO DOCTOR!
Inhalation	Burning sensation. Cough. Dizziness. Headache. Laboured breathing. Nausea. Shortness of breath. Sore throat. Vomiting. Symptoms may be delayed (see Notes).	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Half-s position. Refer for m attention.
Skin	MAY BE ABSORBED! Redness. Pain. Serious skin burns. Blisters. (See Inhalation).	Protective gloves. Protective clothing.	Remove contaminat Rinse skin with plent shower. Refer for me attention.
Eyes	Redness. Pain. Severe deep burns.	Face shield or eye protection in combination with breathing protection.	First rinse with plenty several minutes (ren lenses if easily possi to a doctor.
Ingestion	Abdominal pain. Burning sensation. Diarrhoea. Nausea. Vomiting. Weakness. Collapse.	Do not eat, drink, or smoke during work. Wash hands before eating.	Rinse mouth. Do NC vomiting. Refer for m attention.

SPILLAGE DISPOSAL	PACKAGING & LABELLING	

Evacuate danger area! Consult an expert! Ventilation. Remove vapour with fine water spray. Gas-tight chemical protection suit including self-contained breathing apparatus.	T+ Symbol C Symbol R: 26/27/28-35 S: (1/2-)7/9-26-36/37/39-45 UN Hazard Class: 8 UN Subsidiary Risks: 6.1 UN Pack Group: I	Do not transport with food and feedstuffs.

EMERGENCY RESPONSE	SAFE STORAGE
Transport Emergency Card: TEC (R)-80S1052 or 80GCT1-I NFPA Code: H 3; F 0; R 2	Fireproof. Separated from food and feedstuffs. See Chemical Dangers. Cool. Keep in a well-ventilated room.

IMPORTANT DATA

Physical State; Appearance
COLOURLESS GAS OR COLOURLESS FUMING LIQUID, WITH PUNGENT ODOUR.

Chemical dangers
The substance is a strong acid, it reacts violently with bases and is corrosive. Reacts violently with many compounds causing fire and explosion hazard. Attacks metal, glass, some forms of plastic, rubber and coatings.

Occupational exposure limits
TLV: (as F) 0.5 ppm as TWA, 2 ppm (Ceiling value); BEI issued; (ACGIH 2005).
MAK: 1 ppm, 0.83 mg/m³; Peak limitation category: I (2); Pregnancy risk group: C;
MAK: BAT 7 mg/g creatinine; (DFG 2005).

Routes of exposure
The substance can be absorbed into the body by inhalation, through the skin and by ingestion.

Inhalation risk
A harmful concentration of this gas in the air will be reached very quickly on loss of containment.

Effects of short-term exposure
The substance is corrosive to the eyes, the skin and the respiratory tract. Inhalation of this gas or vapour may cause lung oedema (see Notes). The substance may cause hypocalcemia. Exposure above the OEL may result in death. The effects may be delayed. Medical observation is indicated.

Effects of long-term or repeated exposure
The substance may cause fluorosis.

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Boiling point: 20°C Melting point: -83°C Relative density (water = 1): 1.0 as liquid at 4°C Solubility in water: very good Vapour pressure, kPa at 25°C: 122 Relative vapour density (air = 1): 0.7	

NOTES

The occupational exposure limit value should not be exceeded during any part of the working exposure.
The symptoms of lung oedema often do not become manifest until a few hours have passed and they are aggravated by physical effort. Rest and medical observation are therefore essential.
Immediate administration of an appropriate inhalation therapy by a doctor or a person authorized by him/her, should be considered.
Turn leaking cylinder with the leak up to prevent escape of gas in liquid state.
Depending on the degree of exposure, periodic medical examination is suggested.
UN number for hydrogen fluoride in aqueous solution: 1790, hazard class 8, subsidiary hazard 6.1, pack group I (>60%).
Card has been partly updated in April 2005. See sections Occupational Exposure Limits, Emergency Response.