MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: PRINCIPLES OF CHEMICAL ENGINEERING

CODE: CHEP101/HCHE 111

SESSIONAL EXAMINATIONS
NOVEMBER 2022

DURATION: 3 HOURS

EXAMINER: MR D. NYADENGA

INSTRUCTIONS

1. *Answer **All** questions in Section A*
2. *Answer **any two** questions in Section B*
3. *Start a new question on a fresh page*
4. *Total marks 100*

Additional material(s): *Periodic Table, Calculator, Steam Tables, Conversions Table*

Section A (Answer ***All*** questions**)**

QUESTION A1

a) An orifice meter is used to measure flow rate in pipes. The flow rate is related to the pressure drop by an equation of the form:

$$u = c\sqrt{\frac{\Delta P}{\rho}}$$

where u = fluid velocity, ΔP = pressure drop, ρ = density of the flowing fluid and c = constant of proportionality

Determine the units of c in the SI system of units. [5]

b) The following equation is proposed to calculate the pressure drop (ΔP) across a length of pipe (L) due to flow through the pipe:

$$\Delta P = \frac{1}{2}v^2\left(\frac{L}{D}\right)f$$

where v is the average velocity of the fluid flowing through the pipe, D is the diameter of the pipe and f is a dimensionless coefficient.

i. Determine the dimensional consistency of the equation. [6]

ii. If not dimensionally consistent, determine the process variable that is missing at the RHS for it to be dimensionally consistent. [4]

QUESTION A2

a) Phosphoric acid (H_3PO_4) is a colourless, deliquescent acid used in the manufacture of fertilisers and as a flavouring agent in drinks. For a given 10 wt % phosphoric acid solution of specific gravity 1.10 determine:

i. The mole fractions of H_3PO_4 and H_2O in the solution. [6]

ii. The volume in US gallons of this solution which would contain 1 gmol H_3PO_4. [6]

b) Figure 1 shows how pressure difference between two points of a moving fluid is measured.

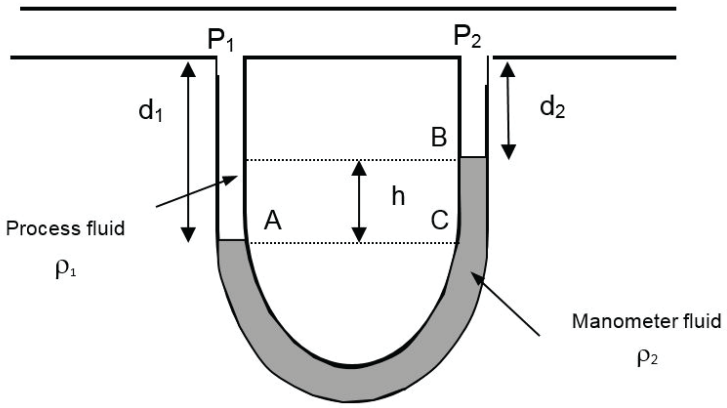

Figure 1

i. Show that $P_1 - P_2 = (\rho_2 - \rho_1)gh$ [4]

ii. Calculate the pressure difference $(P_1 - P_2)$ in **bar** when ρ_1 = 0.91 g/cm^3, ρ_2 = 13.546 g/cm^3 and h = 1.75 in. [6]

c) Fifty kilograms of bismuth (MW = 209) is heated along with ten kilograms of sulfur to form Bi_2S_3 (MW = 514) according to the reaction:

$$2Bi + 3S \longrightarrow Bi_2S_3$$

The degree of completion is 60%. Determine:

i. The limiting reactant. [5]

ii. The percent conversion of the excess reactant. [4]

iii. The mass of Bi_2S_3 produced. [4]

Section B (Answer ***any two*** questions)

QUESTION B1

a) Define the term *combustion*. [1]

b) State the products of complete combustion of carbon and hydrogen. [2]

c) Differentiate between a wet flue gas analysis and an Orsat analysis. [2]

d) 300 kg of C_8H_{18} is burnt in 12% excess air (Air contains 21 mol % O_2 and 79 mol % N_2) to ensure complete combustion. The chemical reaction is as follows:

$$C_8H_{18} + \frac{25}{2}O_2 \longrightarrow 8CO_2 + 9H_2O$$

Calculate:

i. the number of moles of CO_2 and H_2O produced. [6]

ii. the number of moles of O_2 in excess. [4]

iii. the number of moles of N_2 supplied. [4]

iv. the composition of the flue gases on a **dry basis**. [6]

QUESTION B2

a) Give reasons for the presence of the following streams in a multiple unit processing circuit:

i. Recycle stream [2]

ii. Purge stream [1]

iii. Bypass stream [1]

iv. Make-up stream [1]

b) In an evaporative crystallisation process, feed solution containing 15 wt % KCl and 85 wt % water at a rate of 400 kg/h is mixed with recycle and fed to an evaporator, which evaporates some of the water so that the concentrated solution has a KCl mass fraction of 0.38. This solution is fed to a crystalliser and filter. The resulting filter cake contains KCl crystals and saturated KCl solution containing 28 wt % KCl. The crystals are 84 % of the total weight of the filter cake. The rest of the saturated KCl solution (filtrate) is recycled. This is shown in Figure 2.

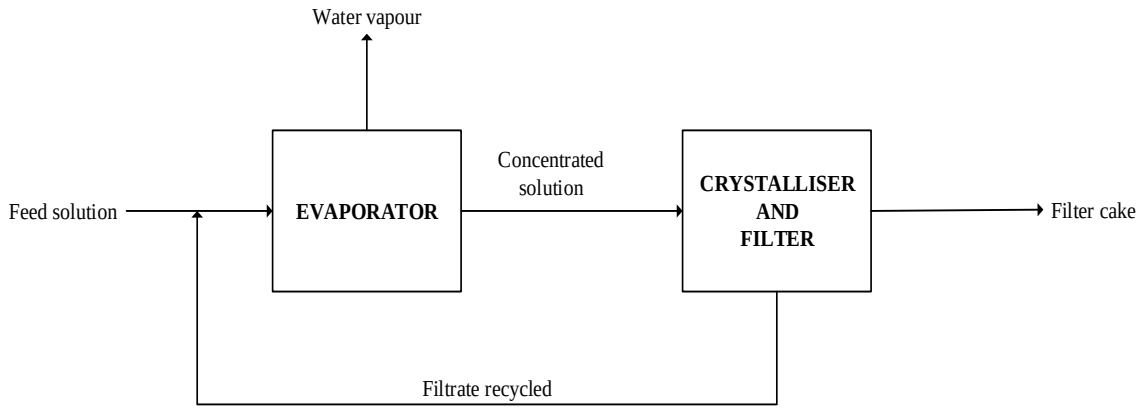

Figure 2

Calculate:

a) The flow rate of crystals leaving the system.

b) The flow rate of water vapour.

c) The flow rate of recycle stream. [20]

QUESTION B3

a) Define the following terms in relation to energy balance:

i. Isolated system [1]

ii. Heat [1]

b) Determine the phase of water, saturation temperature, specific volume and specific enthalpy under the following state conditions:

i. 100 °C and 5 bar [4]

ii. 40 bar and 400 °C [4]

c) A well-insulated turbine operating at steady state develops 23 MW of power for a steam flow rate of 40 kg/s. The steam enters at 350 °C with a velocity of 35 m/s and exits as saturated vapour at 0.045 bar with a velocity of 120 m/s. Determine the inlet pressure in bars and the temperature of steam at the exit point. [15]

END OF EXAMINATION