MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: PRINCIPLES OF CHEMICAL ENGINEERING

CODE: CHEP101

SESSIONAL EXAMINATIONS
JUNE 2023

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, Steam Tables, Conversions Table*

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

QUESTION 1

a) State any ***two*** base quantities and their respective SI units. [4]

b) The volumetric flow rate (q) over a rectangular weir is given by:

$$q = 0.415(L - 0.2h_0){h_0}^{2.5}\sqrt{2g}$$

where L is crest height, h_0 is the weir head with units of length, g is acceleration due to gravity and all numeric figures are dimensionless.

Determine whether the equation is dimensionally consistent. [7]

c) The density of a fluid is given by the empirical equation:

$$\rho = 70.5e^{(8.27\times10^{-7}P)}$$

where ρ is density in $\boldsymbol{lb_m/ft^3}$ and P is pressure in $\boldsymbol{lb_f/in^2}$

i. If the equation is dimensionally consistent, determine the units of ***70.5*** and $\boldsymbol{8.27\times10^{-7}}$. [3]

ii. Calculate the density in $\boldsymbol{g/cm^3}$ for a pressure of 9×10^6 Pa. [6]

QUESTION 2

a) The volumetric flow rate of CCl_4 (ρ = 1.595 g/cm^3) in a pipe is 100 in^3/min. Calculate the molar flow rate of CCl_4 in lbmol/day. [8]

b) A mixture is 10 mol % ethyl alcohol (C_2H_5OH), 75 mol % ethyl acetate ($C_4H_8O_2$) and 15 mol % acetic acid (CH_3COOH). Calculate the mass fraction of ethyl acetate. [8]

c) The pressure gauge on the steam condenser for a turbine indicates 345.44 in of water *vacuum*. The barometer reading is 30.4 in of Hg. Calculate the absolute pressure in the steam condenser in ***kPa***. [6]

d) 0.4 kgmol of dichloroethane ($C_2H_4Cl_2$) are produced when 50 kg of ethane (C_2H_6) are mixed with 135 kg of chlorine (Cl_2) according to the reaction:

$$C_2H_6 + 2Cl_2 \longrightarrow C_2H_4Cl_2 + 2HCl$$

i. Determine the excess reactant. [5]

ii. Calculate the fraction degree of completion of the reaction. [3]

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

QUESTION 3

a) Differentiate between ***wet flue gas analysis*** and ***dry flue gas analysis***. [2]

b) 400 kg of C_7H_{16} is supplied for combustion in air (Air contains 21 mol % O_2 and 79 mol % N_2). 80 % of the C_7H_{16} undergoes complete combustion whilst the rest is incompletely combusted. The chemical reactions are as follows:

$$C_7H_{16} + 11O_2 \longrightarrow 7CO_2 + 8H_2O$$

$$C_7H_{16} + \frac{15}{2}O_2 \longrightarrow 7CO + 8H_2O$$

Calculate:

i. the number of moles of O_2 supplied. [7]

ii. the number of moles of N_2 supplied. [5]

iii. the number of moles of CO_2 and CO produced. [4]

iv. the number of moles of H_2O produced. [5]

v. the mole fraction of CO in the flue gas on a **dry basis**. [2]

QUESTION 4

a) Define *steady state conditions*. [1]

b) Give ***two*** differences between a *batch process* and *continuous process*. [4]

c) Fresh orange juice with a feed rate of 250 kg/h contains 20 % solids and the balance is water. The desired juice concentration is 50 % solids. This is achieved by letting some of the feed stream bypass the evaporator. In the evaporator, 80% of the water entering is evaporated. Figure 1 shows the whole process.

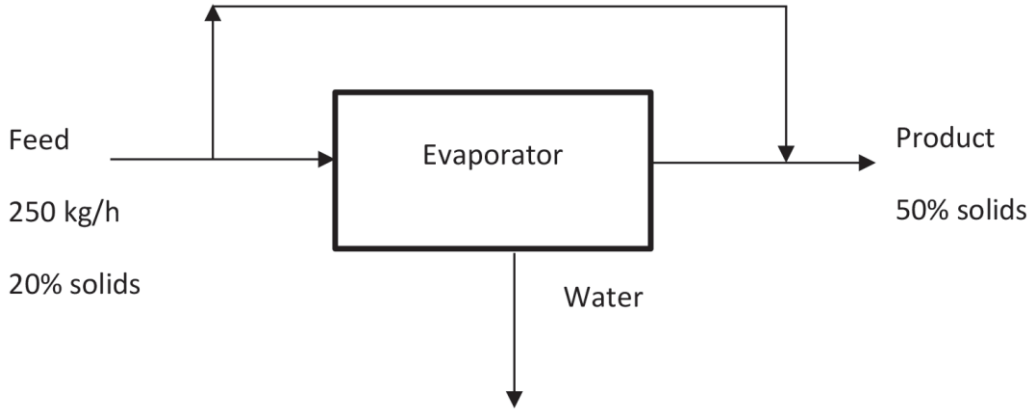

Figure 1

Determine the flow rates of all the streams in the process. [10]

d) Figure 2 shows a closed-circuit grinding flowsheet for processing minerals.

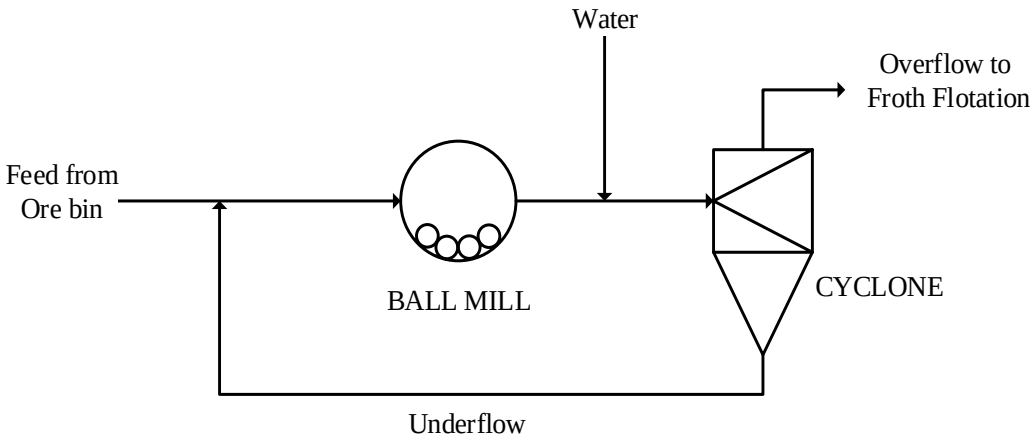

Figure 2

The feed from the ore bin contains 95 % solids and 5 % moisture (water) by mass. The mass flow rate of the dry ore (solids) in the overflow is 25 t/h. The cyclone feed contains 33 % solids, the cyclone underflow 65 % solids and the

cyclone overflow 15 % solids by mass. Calculate:

i. The mass flow rate of the recycle stream.

ii. The amount of water required to dilute the ball mill discharge. [10]

QUESTION 5

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

i. Closed system [1]

ii. Work [1]

iii. Adiabatic process [1]

b) Determine the phase, saturation temperature, specific volume and specific enthalpy of water at 75 ℃ and 0.5 bar. [4]

c) A turbine operating at steady state develops 36 MW of power for a steam flow rate of 317 466 lb_m/h, dissipating 4 MW of heat in the process. The steam enters at 450 ℃ and exits as wet steam at 54 ℃ and dryness fraction of 88.7 %. Determine the pressure of steam at the **entry** and **exit** points. [18]

END OF EXAMINATION