UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

SCHOOL OF ENGINEERING

MAIN EXAMINATIONS: JUNE 2023

COURSE AND CODE: CHEMICAL ENGINEERING PRINCIPLES 1 ENCH1EA

DURATION: 2 HOURS

TOTAL MARKS: 100

INTERNAL EXAMINERS: Prof AH. Mohammadi
Mrs. N Maseko

INTERNAL MODERATOR: Dr. N.M. Mkhize

EXTERNAL MODERATOR: Prof M. Chetty

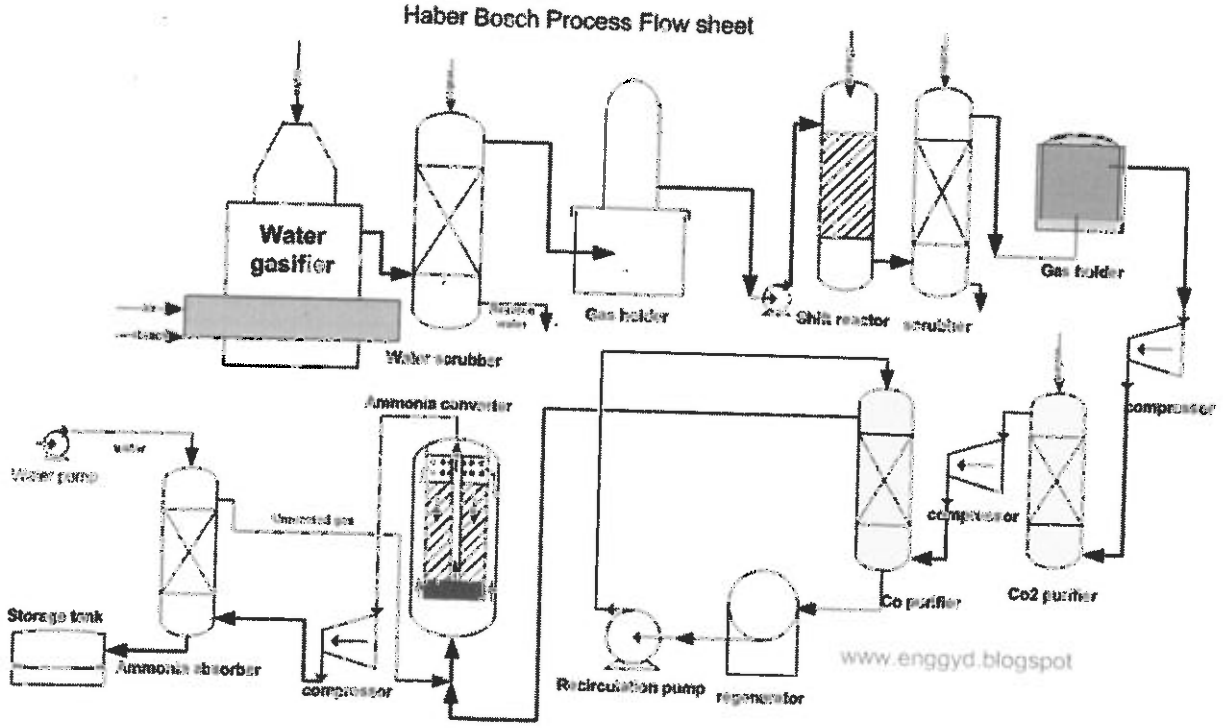
INSTRUCTIONS:

1. **ALL** questions should be attempted.
2. Any programmable or non-programmable calculator may be used provided it has been cleared of any information that would subvert the purpose of the examination.
3. Calculations must be shown in sufficient detail to illustrate your understanding of the procedure.
4. **Two answer books are provided. Label them Book A and Book B. Answer Section A in Book A and Section B in Book B.**

SECTION A

QUESTION 1

Process flow diagram (PFD) of the Haber-Bosch process for ammonia production is given in the following picture. Sketch a Block Flow Diagram (BFD) for this process.



TOTAL /20/

QUESTION 2

(*i*) What category of unit operation is a fan?
(*a*) Separator
(*b*) Reaction Unit
(*c*) Heat Transfer Unit
(*d*) Transport Unit

(1.5)

(*ii*) What category of unit operation is a condenser?
(*a*) Separator
(*b*) Transport Unit

(*c*) Reaction Unit
(*d*) Heat Transfer Unit

(1.5)

(*iii*) What category of unit operation is a conveyor belt?
(*a*) Transport Unit
(*b*) Separator
(*c*) Heat Transfer Unit
(*d*) Reaction Unit

(1.5)

(*iv*) What category of unit operation is a furnace?
(*a*) Heat Transfer Unit
(*b*) Transport Unit
(*c*) Separator
(*d*) Other

(1.5)

(*v*) What category of unit operation is a water desalination unit?
(*a*) Reaction Unit
(*b*) Separator
(*c*) Transport Unit
(*d*) Other

(1.5)

TOTAL /7.5/

QUESTION 3

(*i*) Which of the following unit operations can be used to separate ethanol from water, which are completely miscible in eachother?
a) Absorption unit
b) Liquid-liquid extractor
c) Distillation column
d) Leaching unit

(1.5)

(*ii*) By which unit operation, a mixture of nitrogen and hydrogen can be converted to ammonia?
a) Adsorption unit
b) Absorption unit
c) Reaction vessel
d) Distillation unit

(1.5)

(*iii*) Which of the following unit operations can be used to remove H_2S from natural gas?
a) Leaching unit
b) Liquid-liquid extraction unit
c) Distillation unit
d) Absorption unit

(1.5)

(*iv*) Which unit operation can be used to boost gas pressure?
a) Pump
b) Compressor
c) Mixer-Settler
d) Conveyor

(1.5)

(*v*) By which unit operation, water and crude oil are separated? Water and crude oil are completely immiscible in eachother.
a) Adsorption unit
b) Distillation unit
c) Leaching unit
d) Mixer-Settler (Decanter)

(1.5)

TOTAL /7.5/

QUESTION 4

(*i*) A crude oil has a specific gravity of 0.92. Specific gravity is defined as: Specific Gravity = $\frac{\text{Density of a Substance}}{\text{Density of Water}}$ where water density is 62.43 lb/ft^3 (or 1 g/cm^3).

(a) What is its density in g/cm^3?
(b) What is its specific volume in cm^3/g?
(c) What is its density in lb/ft^3?
(d) What is the mass of 8 cm^3 of this crude oil?
(e) What volume is occupied by 3 g?

(7.5)

(*ii*) Convert the following data:

a) The mass of a chemical is 112 pounds mass (lb_m), what is this in kg?
b) The density of a chemical is 1475 lb_m/ft^3, what is this in kg/m^3?
c) The thermal conductivity of a material is 12 Btu/(ft.h.°F), what is this in W/(m.K)?
d) The specific heat capacity of a material is 1872 Btu/(lb_m.°F), what is it in J/(kg.K)?
e) The maximum operating pressure of a vessel is 24 lb_f/in^2, what is it in bar?

(7.5)

Unit Conversion Data

1ft =12in= 0,3048m
1lb_m = 0,454kg
1lb_f = 4,448N
1Btu = 1054,19J
1 bar = 100 000Pa = 100 000 N/m^2
A temperature rise of 1°C is equivalent to a temperature rise of 1,8°F
To convert from degrees Fahrenheit to degrees Celcius (absolute temperature)
T (°C) = [T(°F) – 32] x 5/9

T(K) = T(°C) + 273.15

TOTAL /15/

SECTION B

QUESTION 5

An aqueous solution of sodium hydroxide contains 20.0% NaOH by mass. It is desired to produce an 8.0% NaOH solution by diluting a stream of the 20% solution with a stream of pure water.

Using a basis 100 kg/s of the 20% feed solution;

a) Draw and label a process flowchart of the above process

(3)

b) How would you simplify the general mass balance equation based on this given process description? Explain why you have decided to eliminate some terms.

(3)

c) Determine the flowrates of the unknown streams

(5)

d) Calculate the ratios (litres H_2O/kg feed solution) and (kg product solution/kg feed solution). water density?

(5)

e) Calculate the molar flow rate of sodium hydroxide in the output stream

(3)

f) What is a difference between a batch and a continuous process?

(3)

TOTAL/22/

QUESTION 6

A cylinder with a movable piston contains 4.00 L of a gas at 30 °C and 5.00 bar. The piston is slowly moved to compress the gas to 8.00 bar:

a) Considering the system to be the gas in the cylinder and neglecting potential energy, write and simplify the closed-system energy balance. DO NOT assume that the process is isothermal.

(3)

b) Suppose the process is carried out isothermally, and the compression work done on the gas equals 7.65 L-bar, If the gas is ideal so that $\hat{U}$ a function of only temperature, how much heat (in Joules) is transferred to or from (state which) the surroundings.

(3)

c) Suppose instead that the process is adiabatic and that U increases as T increases. Is the final system temperature greater than, equal to, or less than 30°C? (Briefly state your reasoning)

(3)

TOTAL/9/

QUESTION 7

Six hundred kg/h of steam drives a turbine. The steam enters the turbine at 60 atm and 550 °C at a linear velocity of 45 m/s, and leaves at a point 15 m below the turbine inlet at atmospheric pressure and a velocity of 190 m/s. The turbine delivers shaft work at a rate of 70 kW, and the heat loss from the turbine is estimated to be -10^{-4} kcal/h. Use the gravitational acceleration of $9.81 m/s^2$

a) Calculate the rate of change in enthalpy for this process in kJ/s

(13)

b) Calculate the specific enthalpy change associated with the process in kJ/kg

(4)

c) Is the work done on the system or by the system? Explain your answer

(2)

TOTAL/19/