Charles Darwin University

Final Examination

Family Name						
Given Name/s						
Student Number						
Teaching Period	Semester 2, 2017					

ENG142 – Concepts of Chemical Engineering	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes

INSTRUCTIONS TO CANDIDATES

EXAM CONDITIONS
<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.
This is a CLOSED BOOK examination
Any non-programmable calculator is permitted
No handwritten notes are permitted
No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 16 Page Book 1 x Scrap Paper Formula Sheet/s Reference Information

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Question 1. (20 marks)

Acrylonitrile (C_3H_3N) is produced in the reaction of propylene (C_3H_6), ammonia (NH_3) and oxygen:

$$C_3H_{6(g)} + NH_{3(g)} + \frac{2}{3}O_{2(g)} \rightarrow C_3H_3N_{(g)} + 3H_2O_{(g)}$$

The feed contains 10 mole% propylene, 12 mole% ammonia and 78 mole% of air and the product stream is a gaseous mixture. Determine:

a) which reactant is limiting, and (10 marks)
b) the molar composition of the product stream for a 30% conversion of the limiting reactant. (10 marks)

Note: air is a mixture of oxygen and nitrogen containing 21 mole% oxygen and 79 mole% nitrogen.

Question 2. (20 marks)

Gasoline $\left(\rho = 50\ {lb_m}/{ft^3}\right)$ is to be siphoned from a tank. The friction loss in the line is $F = 0.8\ \frac{ft\ lb_f}{lb_m}$. Estimate how long it will take to siphon $5.0\ gal$, neglecting the change in liquid level in the gasoline tank during this process and assuming that both the tank and the receiving vessel are vented to the atmosphere.

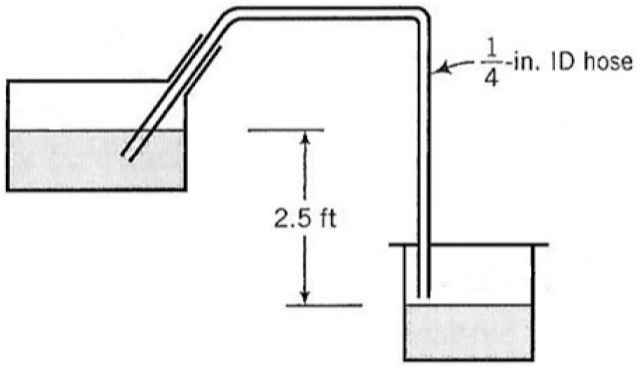

Figure 1

Question 3. (8 marks)

Gas in a tank contains a poison at a concentration c_T, but the gas is leaking into the surrounding room at a rate of $T\ {cm^3}/{min}$. Meanwhile, an air conditioner brings fresh air into the room at a rate of $A\ {cm^3}/{min}$. The air in the room is well mixed and leaves through an open window (with the same concentration as in the room). The densities of all the gases are the same. Initially, the concentration of poison in the room (c_R) will rise, but it eventually will reach a steady value. In terms of the given symbols, what is that steady concentration?

Question 4. (15 marks)

A double-pipe counter-flow heat exchanger is used to cool ethylene glycol $\left(C_P = 2560\ {}^{J}/_{kg\ ^\circ\mathrm{C}}\right)$ flowing at a rate of $3.5\ {}^{kg}/_{s}$ from $80\ ^\circ\mathrm{C}$ to $40\ ^\circ\mathrm{C}$. Cooling water $\left(C_P = 4180\ {}^{J}/_{kg\ ^\circ\mathrm{C}}\right)$ enters at $20\ ^\circ\mathrm{C}$ and leaves at $55\ ^\circ\mathrm{C}$.

The overall heat transfer coefficient based on the inner surface area of the tube is $U = 250\ {}^{W}/_{m^2 ^\circ\mathrm{C}}$.

Calculate:

a) the duty heat (rate of heat transfer) of the heat exchanger, (5 marks)
b) the mass flow rate of water, and (5 marks)
c) the heat transfer surface area on the inner side of the tube. (5 marks)

Question 5. (12 marks)

A liquid solution of species A with a concentration of $0.8\ \frac{mol}{L}$ enters a CSTR reactor at a flow rate of $20\ \frac{L}{s}$, where it is consumed by an irreversible reaction $A \rightarrow P$. The reaction rate is given by $r_{reaction,A} = k_r c_A$, where k_r is equal to $0.02\ s^{-1}$ and the volume of the reactor is 8000 L.

a) What is the order of the reaction? (2 marks)
b) What is the concentration of component A in the exit stream? (10 marks)

Question 6. (25 marks)

The production of calcium hydroxide $\left(Ca(OH)_{2(s)}\right)$ requires the reaction of calcium carbide $\left(CaC_{2(s)}\right)$ and water as shown by the chemical reaction:

$$CaC_{2(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + C_2H_{2(g)}$$

This reaction is an exothermic reaction and releases $125.4\ kJ$ per mole of calcium hydroxide produced. The feed rate of $CaC_{2(s)}$ is 10 000 kg/day and the purity is 98.2 %. The reactor is kept at a constant temperature by using cooling water in a jacket surrounding the reactor.

a) Calculate the heat released from the reactor into the jacket in one day. (10 marks)
b) Calculate the mass flow rate in $\frac{kg}{h}$ of cooling water required if the cooling water enters the reactor as liquid at $11^\circ\mathrm{C}$ and leaves as vapour at $100^\circ\mathrm{C}$. (10 marks)
c) If the cooling water costs \$1.91/kL, calculate the annual cost of cooling water. (5 marks)

Note: Use the steam tables provided.