

**UNIVERSITY COLLEGE TATI (UC TATI)****FINAL EXAMINATION QUESTION BOOKLET**

COURSE CODE	: DTC 2143	571
COURSE	: TRANSPORT PROCESS	
SEMESTER/SESSION	: 2-2024/2025	
DURATION	: 3 HOURS	

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. You are allowed to bring a **sheet A4 Paper** (Formula and notes only).
3. All answers should be written in answer booklet.
4. Write legibly and draw sketches wherever required.
5. If in doubt, raise your hands and ask the invigilator.

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO**

**THIS BOOKLET CONTAINS 8 PRINTED PAGES INCLUDING COVER PAGE**

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**QUESTION 1**

- a) State and briefly describe three (3) type of pressure. (6 marks)
- b) Explain what is gas law (2 marks)
- c) A gas mixture contains the following components and partial pressures:  
CO<sub>2</sub>, 75 mm Hg; CO, 50 mm Hg; N<sub>2</sub>, 595 mm Hg; O<sub>2</sub>, 26 mm Hg.  
Calculate the total pressure and the composition in mole fraction. (6 marks)
- d) A fluid with a specific heat capacity  $C_{pm} = 2.45 \text{ kJ/kg}\cdot\text{K}$  is being cooled in a heat exchanger from 385 K to 355 K and flows inside the tube at a rate of 3000 kg/h. A flow of 1200 kg water/h enters at 290 K for cooling and flows outside the tube. The streams are countercurrent.
- Calculate the water outlet temperature (5 marks)
  - Calculate the log mean temperature difference  $\Delta T_{lm}$  (3 marks)
  - Calculate heat-transfer area if the overall  $U_i = 300 \text{ W/m}^2\cdot\text{K}$  (3 marks)

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**QUESTION 2**

- a) Describe cold air theory and where is the freezer compartment put in a fridge? (Clarify your answer with appropriate sketch) (6 marks)
- b) Oil flowing at the rate of 5.04 kg/s ( $C_{pm} = 2.09 \text{ kJ/kg} \cdot \text{K}$ ) is cooled in a 1-2 heat exchanger from 366.5 K to 344.3 K by 2.02 kg/s of water entering at 283.2 K. The overall heat-transfer coefficient  $U_o$  is  $340 \text{ W/m}^2 \cdot \text{K}$ .
- Calculate the outlet water temperature  $T_{co}$  (6 marks)
  - Calculate log mean temperature difference  $\Delta T_{lm}$  (5 marks)
  - Calculate the mean temperature difference  $\Delta T_m$  in the exchanger (5 marks)
  - Calculate the area required (3 marks)

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**QUESTION 3**

- a) Describe double pipe, shell and tube and cross flow heat exchangers  
(clarify your answers with appropriate sketches) (9 marks)
- b) Helium and nitrogen gas are contained in a conduit 5 mm in diameter and 0.1 m long at 298 K and a uniform constant pressure of 1.0 atm abs. The partial pressure of He at one end of the tube is 0.060 atm and 0.020 atm at the other end. The diffusivity can be obtained from Table 1 (refer appendix). Calculate the following for steady-state equimolar counterdiffusion.
- Flux of He in  $\text{kg}\cdot\text{mol}/\text{s}\cdot\text{m}^2$  (9 marks)
  - Flux of  $\text{N}_2$ . (2 marks)
  - Partial Pressure of He at a point 0.05 m from either end. (5 marks)

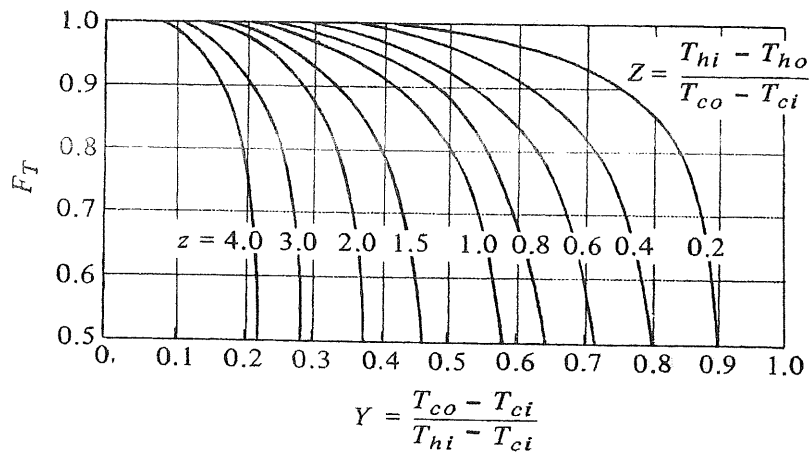
**QUESTION 4**

- a) Explain molecular diffusion (2 marks)
- b) Predict the diffusivity of the enzyme urease in a dilute solution in water at 298 K using the modified Polson equation and compare the result with the experimental value in Table 2 (refer appendix). (7 marks)
- c) The solute HCl (A) is diffusing through a thin film of water (B) 2.0 mm thick at 283 K. The concentration of HCl at point 1 at one boundary of the film is 12.0 wt % HCl (density  $\rho_1 = 1060.7 \text{ kg/m}^3$ ), and at the other boundary at point 2 it is 6.0 wt % HCl ( $\rho_2 = 1030.3 \text{ kg/m}^3$ ). The diffusion coefficient of HCl in water is  $2.5 \times 10^{-9} \text{ m}^2/\text{s}$ . Assuming steady state and one boundary impermeable to water, calculate the flux of HCl in  $\text{kg mol/s}\cdot\text{m}^2$ . (16 marks)

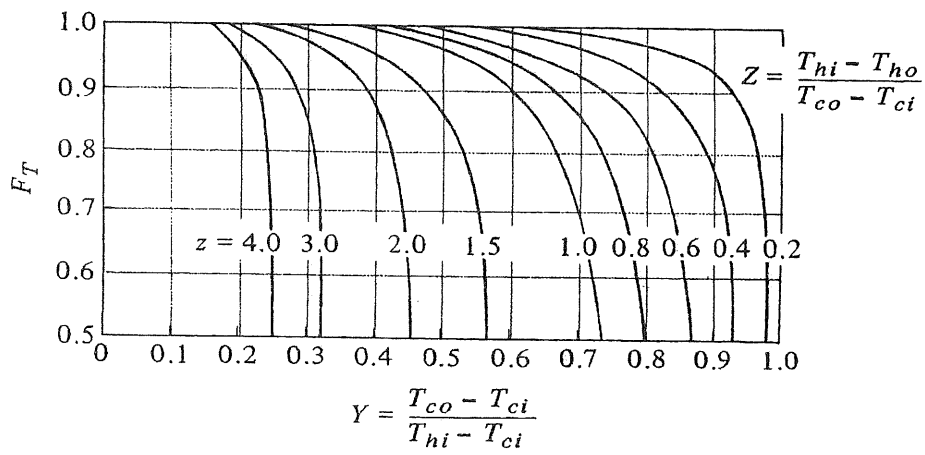
-----End of question-----

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Appendix



(a)



(b)

Figure 1. Correction Factor  $F_T$  to log mean temperature difference: (a) 1-2 and 1-4 exchangers, (b) 2-4 exchangers

Table 1. Diffusion Coefficients of Gases at 101.32 kPa Pressure

System	Temperature		Diffusivity [(m <sup>2</sup> /s)10 <sup>4</sup> or cm <sup>2</sup> /s]	Ref.
	°C	K		
Air-NH <sub>3</sub>	0	273	0.198	(W1)
Air-H <sub>2</sub> O	0	273	0.220	(N2)
	25	298	0.260	(L1)
	42	315	0.288	(M1)
Air-CO <sub>2</sub>	3	276	0.142	(H1)
	44	317	0.177	
Air-H <sub>2</sub>	0	273	0.611	(N2)
Air-C <sub>2</sub> H <sub>5</sub> OH	25	298	0.135	(M1)
	42	315	0.145	
Air-CH <sub>3</sub> COOH	0	273	0.106	(N2)
Air- <i>n</i> -hexane	21	294	0.080	(C1)
Air-benzene	25	298	0.0962	(L1)
Air-toluene	25.9	298.9	0.086	(G1)
Air- <i>n</i> -butanol	0	273	0.0703	(N2)
	25.9	298.9	0.087	
H <sub>2</sub> -CH <sub>4</sub>	25	298	0.726	(C2)
H <sub>2</sub> -N <sub>2</sub>	25	298	0.784	(B1)
	85	358	1.052	
H <sub>2</sub> -benzene	38.1	311.1	0.404	(H2)
H <sub>2</sub> -Ar	22.4	295.4	0.83	(W2)
H <sub>2</sub> -NH <sub>3</sub>	25	298	0.783	(B1)
H <sub>2</sub> -SO <sub>2</sub>	50	323	0.61	(S1)
H <sub>2</sub> -C <sub>2</sub> H <sub>5</sub> OH	67	340	0.586	(T1)
He-Ar	25	298	0.729	(S2)
He- <i>n</i> -butanol	150	423	0.587	(S2)
He-air	44	317	0.765	(H1)
He-CH <sub>4</sub>	25	298	0.675	(C2)
He-N <sub>2</sub>	25	298	0.687	(S2)
He-O <sub>2</sub>	25	298	0.729	(S2)
Ar-CH <sub>4</sub>	25	298	0.202	(C2)
CO <sub>2</sub> -N <sub>2</sub>	25	298	0.167	(W3)
CO <sub>2</sub> -O <sub>2</sub>	20	293	0.153	(W4)
N <sub>2</sub> - <i>n</i> -butane	25	298	0.0960	(B2)
H <sub>2</sub> O-CO <sub>2</sub>	34.3	307.3	0.202	(S3)
CO-N <sub>2</sub>	100	373	0.318	(A1)
CH <sub>3</sub> Cl-SO <sub>2</sub>	30	303	0.0693	(C3)
(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O-NH <sub>3</sub>	26.5	299.5	0.1078	(S4)

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Table 2. Diffusion Coefficients for Dilute Biological Solutes in Aqueous Solution

<i>Solute</i>	<i>Temperature</i>		<i>Diffusivity</i> ( $m^2/s$ )	<i>Molecular</i> <i>Weight</i>	<i>Ref.</i>
	$^{\circ}C$	<i>K</i>			
Urea	20	293	$1.20 \times 10^{-9}$	60.1	(N2)
	25	298	$1.378 \times 10^{-9}$		(G5)
Glycerol	20	293	$0.825 \times 10^{-9}$	92.1	(G3)
Glycine	25	298	$1.055 \times 10^{-9}$	75.1	(L3)
Sodium caprylate	25	298	$8.78 \times 10^{-10}$	166.2	(G6)
Bovine serum albumin	25	298	$6.81 \times 10^{-11}$	67 500	(C6)
Urease	25	298	$4.01 \times 10^{-11}$	482 700	(C7)
	20	293	$3.46 \times 10^{-11}$		(S6)
Soybean protein	20	293	$2.91 \times 10^{-11}$	361 800	(S6)
Lipoxidase	20	293	$5.59 \times 10^{-11}$	97 440	(S6)
Fibrinogen, human	20	293	$1.98 \times 10^{-11}$	339 700	(S6)
Human serum albumin	20	293	$5.93 \times 10^{-11}$	72 300	(S6)
$\gamma$ -Globulin, human	20	293	$4.00 \times 10^{-11}$	153 100	(S6)
Creatinine	37	310	$1.08 \times 10^{-9}$	113.1	(C8)
Sucrose	37	310	$0.697 \times 10^{-9}$	342.3	(C8)
	20	293	$0.460 \times 10^{-9}$		(P3)