Charles Darwin University

Final Examination

Family Name						
Given Name/s						
Student Number						
Teaching Period	Semester 1, 2019					

ENG442 – Chemical Engineering Thermodynamics	DURATION	
	Reading Time:	10 minutes
	Writing Time:	120 minutes

INSTRUCTIONS TO CANDIDATES

1. Read all questions carefully.
2. Answer ALL questions in the exam booklet. Only your answers provided in the exam booklet will be marked.
3. Show all working (calculations and sketches).
4. This exam constitutes 50% of the total marks for this Unit.
5. Total marks available on this exam = 100.
6. Use dark blue or black ink.

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 RESTRICTED OPEN BOOK examination

Any non-programmable calculator is permitted

One A4 sheet of handwritten double-sided notes permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
None	1 x 20 Page Book 1 x Scrap Paper Reference Information

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Question 1

A 360 litre pressurised tank is used to store $70kg$ of $CO_{2(g)}$ at 62 ℃. Engineer A calculates the pressure in the tank by using the ideal gas approximation while engineer B prefers to use the Pitzer correlations for real gases. $P_{c,CO_2} = 73.83\ bar$, $T_{c,CO_2} = 304.2K$, $\omega_{CO_2} = 0.224$

a) What are the pressure values calculated by both engineers? (15 marks)
b) Is engineer A putting the process and the staff at risk by using the ideal gas approximation? Support your answer base on the results obtained in part a. (5 marks)

20 marks

Question 2

The partial oxidation of methane at $600K$ is used for the production process of hydrogen (see reaction 1). Engineers discovered that benzene is present as part of the product of the process. They believe that the traces of benzene are because of a parallel reaction (reaction 2).

$$CH_{4(g)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{(g)} + 2H_2 \qquad \text{(reaction 1)}$$

$$CH_{4(g)} + \frac{3}{4}O_{2(g)} \rightarrow \frac{1}{6}C_6H_{6(g)} + \frac{3}{2}H_2O \qquad \text{(reaction 2)}$$

Calculate the Gibbs free energy of reaction two and explain if the idea of the engineers is valid or not.

Species	$\Delta H_{f,298.15}$ $\left(kcal/_{mol}\right)$	$\Delta S_{f,298.15}$ $\left(cal/_{mol\ K}\right)$	$C_P^0\left(cal/_{mol\ K}\right)$
$C_6H_{6(g)}$	19.820	64.340	43.301
$H_2O_{(g)}$	-57.796	45.110	7.907
$CH_{4(g)}$	-17.811	44.500	10.139
$O_{2(g)}$	----	49.00	7.714

30 marks

Question 3

A vapour-compression refrigeration system using CFC-12 (see thermodynamic data provided) rated at 5 tons is employed in a chemical manufacturing plant to maintain the temperature of an evaporator and condenser at $-10℃$ and $35℃$ respectively. The isentropic efficiency of the compressor is reported to be 85%. Calculate:

a) The Mass flow rate of the refrigerant (5 marks)
b) The power consumption of the compressor (5 marks)
c) The amount of heat rejected in the condenser (5 marks)
d) The difference in the COP between the vapour-compression cycle and the Carnot cycle (5 marks)

A rate of 1 ton for a compression refrigeration system is equivalent to 3.516 kW.

20 marks

Question 4

For a binary system, the excess Gibbs free energy of components 1 and 2 at 30℃ is given by $\frac{G^E}{RT} = 0.625x_1x_2$. If the vapour pressures of both components follow the equations below, calculate the composition of the azeotrope.

$$LnP_1^{sat} = 13.71 - \frac{3800}{T} \text{ and } LnP_2^{sat} = 14.01 - \frac{3800}{T}$$

where P_1^{sat} and P_2^{sat} are the saturation pressures of component 1 and 2, respectively and T is the temperature in K.

Hint: if $\frac{G^E}{RT} = Ax_1x_2$, then $Ln(\gamma_1) = Ax_2^2$ and $Ln(\gamma_2) = Ax_1^2$

20 marks

Question 5

Oil is to be cooled from 425K to 340K at a rate of $5000\ ^{kg}/_{h}$ in a parallel flow heat exchanger. Cooling water at a rate of $10000\ ^{kg}/_{h}$ at 295K is available. The mean specific heats of the oil and the water are $2.5\ ^{kJ}/_{kg\ K}$ and $4.2\ ^{kJ}/_{kg\ K}$. Determine the total change in entropy.

10 marks