NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination December 2013

TCE 2104 Chemical Engineering Thermodynamics 1A

Duration of Examination 3 Hours

Instructions to Candidates

1. Answer **Question One** and any other **Three** questions.
2. Show all your steps clearly in your calculation.
3. Start the answers for each question on a new page.

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1. a) With the aid of a relevant example illustrate how the Gibbs free energy depends on temperature and pressure? [7]

   b) A $1.5m^3$ tank contains 520kg of liquid water in equilibrium with pure water vapour, which fills the remainder of the tank. The temperature and pressure are 100°C and 101.33kPa. From a water line at constant temperature of 70°C and a constant pressure of somewhat above 101.33kPa, 760kg of liquid is bled into the tank. If the temperature and pressure in the tank are not to change as a result of the process, how much energy as heat must be transferred to the tank? [8]

   c) Discuss the practical applications of exact differentials and partial derivatives in the study of thermodynamic properties of fluids? [6]

   d) Analyse the two main reasons for inaccuracy in the calculation of thermodynamic properties for the construction of a table or diagram? [4]

2. a) Justify the notion that chemical potentials are more suitable than thermodynamic fugacities or activities to define environmentally determined potentials? [7]

   b) Derive the Maxwell relation equations and explain their practical applications?[8]

   c) Find the values of the residual enthalpy H^R and the residual entropy S^R for n-butane gas at 500K and 50 bar as given by the Redlich/Kwong equation? [10]

Data : $\Omega = 0.08664$ $\psi = 0.42748$ $\alpha T_r = T_r^{1/2}$

3. a) Explain how flow in pipes differs from that in nozzles clearly showing which case is more advantageous and why? [4]

   b) In a steady-state flow process, 1 mol/s of air at 600K and 1 atm is continuously mixed with 2 mol/s of air at 450K and 1 atm. The product stream is at 400K and 1 atm. Determine the rate of heat transfer and the rate of entropy generation for the process? Assume that air is an ideal gas with $C_p = (7/2)R$, that the surroundings are at 300K, and that kinetic and potential energy changes are negligible. [6]

   c) State the equation for the partial molar volume and explain its physical interpretation? [6]

   d) Gas is compressed in a reciprocating compressor from 1 bar to 6 bar. The free air delivery (FAD) is $13dm^3$. The clearance ratio is 0.05. The expansion part of the cycle follows the law $pV^{1.2} = C$. The crank speed is 360rev/min. Calculate the swept volume and the volumetric efficiency? [9]

4. a) Superheated steam originally at P_1 and T_1 expands through a nozzle to an exhaust pressure P_2. Assuming that the process is reversible and adiabatic and that equilibrium is attained, determine the state of the steam at the exit of the nozzle for the following conditions: P_1 = 1 000kPa, T_1 = 275°C and 200kPa. [8]

   b) Derive the continuity equation and illustrate two of its applications? [4]

   c) With the aid of equations define fugacity outlining its importance and how it differs for an ideal gas mixture, ideal solution of gas and real gas mixture. [6]

   d) A rigid tank contains 1 kg of N_2 initially at 300 K and 1 atm. Energy is added to the gas until a final temperature of 600 K is reached. Calculate the entropy change of the N_2 associated with this heating process? [7]
   Data: c_p @ 300K = 29.075 kJ/kmol.K c_p @ 600K =30.086 kJ/kmol.K

5. a) Determine the fugacity, in bars, for $C_2F_4H_2$ for a Redlich-Kwong gas at 90°C and 10 bar? [8]

   Data : T_c = 374.3K P_c = 40.6 bar $\nu = 2.724 m^3/kg$

   b) Water at 45°C and 10kPa enters an adiabatic pump and is discharged at a pressure of 8 600kPa. Assume the pump efficiency to be 0.75. Calculate the work of the pump, the temperature change of the water, and the entropy change of the water. [7]

Data (saturated liquid water at 45°C)

$V = 1\ 010 cm^3/kg$ $\beta = 425\times10^{-6}$ $C_p = 4.178 kJ/kgK$

c) Compare and contrast excess properties and residual properties in the study of thermodynamic properties of fluids? [6]

d) Discuss the two idealizations that facilitate the practical application of equations of balance? [4]

END OF EXAM