NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination May 2014

TCE 2004 Chemical Engineering Thermodynamics

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) Estimate V, U, H and S for 1-butene vapour at 200°C and 70 bar if H and S are set equal to zero for saturated liquid at 0°C. Assume that the only data available are :
   $T_c = 420$ K $P_c = 40.43$ bar $\omega = 0.191$ $T_n = 266.9$K
   $Cp^{ig}/R = 1.967 + 31.630\times10^{-3}T - 9.837\times10^{-6}T^2$ [15]

   b) Consider the steady-state adiabatic, irreversible flow of an incompressible liquid in a horizontal pipe of constant cross-sectional area. Show that:

   i) the velocity is constant [2]

   ii) the temperature increases with direction of flow [3]

   c) Explain how flow in pipes differs from that in nozzles clearly, showing which case is more advantageous and why? [5]

2. a) Discuss the practical applications of exact differentials and partial derivatives in the study of thermodynamic properties of fluids. [6]

   b) A 1.5m^3 tank contains 500kg 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, 750kg of liquid is bled into the tank. If the temperature and pressure in the tank do not change as a result of the process, how much energy, as heat, must be transferred to the tank? [9]

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

d) 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]

3. a) Compare and contrast excess properties and residual properties in the study of thermodynamic properties of fluids. [6]

b) Show from first principles that:

(i) $\frac{V}{RT} = \left[\frac{\partial(G/RT)}{\partial P}\right]_T$ [5]

(ii) $\frac{H}{RT} = -T\left[\frac{\partial(G/RT)}{\partial T}\right]_P$ [5]

c) State the fundamental property relation equations. [4]

d) A high velocity nozzle is designed to operate with steam at 700kPa and 300°C. At the nozzle inlet velocity is 30m/s. Calculate values of the ratio A/A_1 (where A_1 is the cross-sectional area of the nozzle inlet) for the section where pressure is 600, 500 and 400kPa. Assume that the nozzle operates isentropically. [5]

4. a) Determine the enthalpy and entropy changes of liquid water for a change of state from 1 bar and 25°C to 1000 bar and 50°C. The following data for water are available. [10]

T /°C	P/ bar	C_p /J mol^{-1} K^{-1}	V /cm^{3}mol^{-1}	β /K^{-1}
25	1	75.305	18.071	256×10^{-6}
25	1000		18.012	366×10^{-6}
50	1	75.314	18.234	458×10^{-6}
50	1000		18.174	568×10^{-6}

b) State and explain the advantages and draw backs of using thermodynamic tables.[5]

c) Using data from steam tables:

(i) Determine the numerical values of G^L and G^v for saturated liquid and vapour at 1000kPa. [5]

(ii) Determine the numerical values of $\Delta H^{lv}/T$ and ΔS^{lv} at 1000kPa. [5]

5. a) 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. [8]

<u>**Data**</u> (saturated liquid water at 45°C)

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

b) Some expressions for G^E/RT are incapable of representing LLE. An example is the Wilson equation: [5]

$$G^E/RT = -x_1\ln(x_1+x_2\Lambda_{12}) - x_2\ln(x_2+x_1\Lambda_{21})$$

Show that the stability criteria are satisfied for all values of Λ_{12}, Λ_{21} and x_1.

c) Define the tem partial molar property and clearly show its application in the practical field of chemical engineering. [5]

d) Justify the notion that the Gibbs energy, Helmholtz energy and partition function serve as generating functions for other thermodynamic properties. Include all the relevant equations in your justification. [7]

END OF EXAM