NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Supplementary Examination 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) Using data from steam tables:
   (i) Determine the numerical values of G^L and G^v for saturated liquid and vapour at 1000kPa. [6]

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

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

   c) Describe how compression is attained in compressors. [5]

   d) Outline the conditions under which residual properties are valid. [5]

2. a) Derive the Maxwell equations. [10]

   b) Superheated steam originally at P_1 and T_1 expands through a nozzle to an exhaust pressure P_2. Assuming 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:
   i) P_1 =1000kPa, t_1=260°C, and P_2 =200kPa [8]

c) Define chemical potential highlighting its meaning for a pure species, meaning when there is only one phase present and its significance in thermodynamics. [7]

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

   b) Derive the continuity equation and illustrate two of its applications. [6]

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

   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. [9]

4. a) 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. [8]

   b) Outline how the Mach number (M) finds practical application in duct flow of compressible fluids. [5]

   c) Justify the need to study energy balances in thermodynamics of flow processes.[6]

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

5. a) The excess enthalpy (heat of mixing) for a liquid mixture of species 1 and 2 at fixed T and P is represented by the equation:

$$H^E = x_1x_2(40\, x_1+20\, x_2)$$

   where H^E is in J/mol. Determine expressions for H^E_1 and H^E_2 as functions of x_1. [10]

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

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

Show that the stability criteria are satisfied for all values of $\Lambda_{12,}$ Λ_{21} and $x_{1.}$ [5]

c) 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. [10]

END OF EXAM