NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
BACHELOR OF ENGINEERING (HONS) DEGREE
Part Two Examination May 2011

TCE 2004 Chemical Engineering Thermodynamics

Duration of Examination 3Hours

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.

---

1. a) Show from first principles that:

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

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

   (iii) $\frac{P}{RT} = \left[\frac{\partial(A/RT)}{\partial V}\right]_T$

   (iv) $\frac{U}{RT} = -T\left[\frac{\partial(A/RT)}{\partial T}\right]_V$ [10]

   b) State the equation that gives the general definition of residual properties and give the thermodynamic properties for which it applies? [2]

   c) State and explain the advantages and draw backs of using thermodynamic tables? [3]

   d) For H_2O at a temperature of 350°C and up to 10 000kPa (100 bar) plot values of f_i and ϕ_i calculated from data in the steam tables vs. P.? [10]

2. a) Explain the industrial application of thermodynamic properties of fluids giving relevant examples? [5]

   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: [8]

i) P_1 =1000kPa, t_1=260°C, and P_2 =200kPa

ii) P_1 =150 (psia), t_1=500°F, and P_2 =30 (psia)

c) 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]

d) Outline the differences between a turbine and a compressor? [2]

3. a) For the system 2-propanol (1)/water (2), the following parameter values are recommended for the Wilson equation:

a_{12} = 437.98 cal/mol a_{21} = 1 238.00 cal/mol

V_1 =76.92 cm^3/mol V_2 = 18.07 cm^3/mol

In addition, the following Antoine equations:

$$\ln P^{sat}{}_1\ /(kPa) = 16.6780 - \frac{3\ 640.20}{T/\ (K) - 53.54}$$

$$\ln P^{sat}{}_2\ /(kPa) = 16.2887 - \frac{3\ 640.20}{T/(K) - 46.13}$$

Assuming the validity of $y_iP = x_i\gamma_iP_i^{sat}$ (i=1,2…..,N) calculate:

(a) P and $\{y_i\}$, for T = 353.15 K and x_1 = 0.25

(b) P and $\{x_i\}$, for T = 353.15 K and y_1 = 0.60

(c) T and $\{y_i\}$, for P = 101.33 K and x_1 = 0.85

(d) T and $\{x_i\}$, for P = 101.33 K and y_1 = 0.40

(e) P^{az}, the azeotropic pressure, and $x_1^{az} = y_1^{az}$, the azeotropic composition, for T = 353.15K. [25]

4. a) State and explain in detail the two idealizations that facilitate the practical applications of equations of balance? [5]

b) With the aid of a diagram illustrate the steps involved in pressure, temperature flash calculations? [10]

c) State the fundamental property relations equations and define each variable stating its units of measurement? [10]

5. a) Calculate the equilibrium constant for vapour-phase hydration of ethylene at 145 and at 145 °C and 320°C using data from heat capacities and property changes of formation?

Data

$$\int_{To}^{T} \frac{\Delta C^{o}_{p}}{R}\, dT = -23.121\ (for\ T = 145°C)\ and = 22.632(for\ T = 320°C)$$

and $$\int_{To}^{T} \frac{\Delta C^{o}_{p}}{R} \frac{dT}{T} = -0.06924(for\ T = 145°C)\ and = 0.01731\ (for\ T = 320°C)$$

[13]

b) Discuss in brief the use of ejectors in thermodynamics of flow processes? [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? [7]

END OF EXAM