



UNIVERSITY OF GHANA
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B.Sc ENGINEERING FIRST SEMESTER EXAMINATION: 2017/2018

DEPARTMENT OF FOOD PROCESS ENGINEERING

FPEN 303: THERMODYNAMICS (2 Credits)

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II

INSTRUCTIONS

TIME: 2HRS

Please read the following INSTRUCTIONS carefully

- [1] Answer THREE questions from SECTION A
- [2] Answers to SECTION A must be written in an Answer Booklet
- [3] Answer ALL questions in SECTION B
- [4] Answers to SECTION B must be written on the question paper
- [5] Write your STUDENT ID NUMBER on all the applicable question sheets and tie them inside the Answer Booklet

SECTION A**Answer THREE questions**

1. A binary mixture consists of acetonitrile (1) and nitromethane (2) which conform closely to Raoult's law. Vapor pressures for the pure species are given by the following Antoine equations:

$$\ln(P_1^{sat}, kPa) = 14.27 - \frac{2,945.5}{t, ^\circ C + 224.0}$$

$$\ln(P_2^{sat}, kPa) = 14.20 - \frac{2,972.6}{t, ^\circ C + 209.0}$$

Determine the bubble point pressure and vapor composition for a mixture of composition $x_1 = 0.6$ at a temperature of $65^\circ C$.

2. Consider the txy-diagram given. At a liquid concentration of $x_1 = 0.5$,
- First, identify the bubble and dew point curves
 - Read the bubble point temperature.
 - What is the composition of the bubble produced?
 - At a temperature of $73^\circ C$, what is the composition of the liquid and vapor in equilibrium with each other?
 - What is the percent of vapour in the vapor-liquid mixture at this temperature?
3. A mixture of the following composition:

	Mol %
Ethane	10
Propane	30
n-butane	60

is brought to a condition of $110^\circ F$ and a pressure P . If the molar fraction of liquid in the system is 0.40, what is pressure P (in psia) and what are the compositions of the liquid and vapour phases?

4. (a) State the criteria for equilibrium in a vapour-liquid mixture.
- (b) Given the excess Gibbs free energy of a solution as:

$$\frac{G^E}{x_1 RT} = B(1 - x_1)$$

find the two activity coefficient expressions arising out of the binary solution model.

- (c) Show whether these expressions satisfy the Gibbs-Duhem equation.

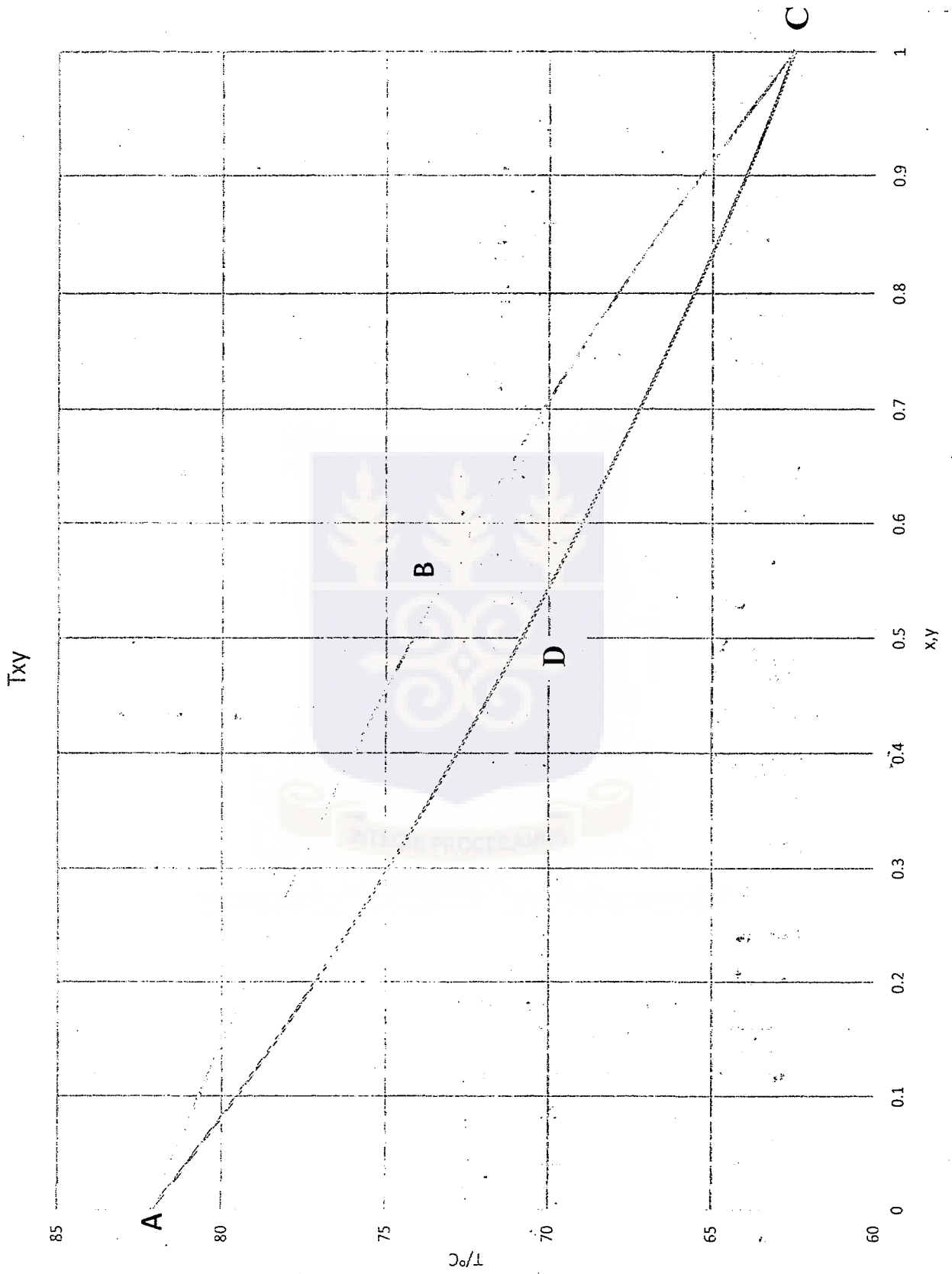
SECTION B

Answer ALL Questions

1. What is the basic equilibrium criterion for species in phase equilibrium?
2. Write down the equation for the Lewis-Randall rule for fugacity of species in an ideal solution.
3. If the fugacity of a pure component at the conditions of an ideal solution is 40 bar and its mole fraction is 0.4, what is its fugacity in the solution according to the Lewis-Randall rule?
4. Write down the equation called the modified Raoult's law
5. For the fundamental relation, $dG = VdP - SdT$, write down the corresponding Maxwell relation
6. Write down the defining equation for chemical potential in terms of a derivative of the Gibbs free energy
7. For an ideal gas mixture of A and B, if the total pressure is 100 kPa and component B has a mole fraction of 0.25, calculate the partial pressure of component A.
8. According to the Gibbs theorem, the properties of an ideal mixture are given in terms of pure species values as:

$$nM^{ig}(T,P) =$$

9. Find the fugacity coefficient of a gaseous species of mole fraction 0.4 and fugacity 25 psia in a mixture at a total pressure of 50 psia.
10. Write down the defining expression for the residual and excess properties M^R and M^E respectively, of a component in a gaseous mixture
11. If the partial molar volumes of the two components of a binary solution are $\bar{V}_A = 30 \text{ m}^3/\text{mol}$ and $\bar{V}_B = 20 \text{ m}^3/\text{mol}$ and the mole fraction of component A is 0.4, find the molar volume of the solution.
12. Using the partial molar properties, \bar{M}_i and the compositions x_i , write an expression for the Gibbs-Duhem equation at constant T and P.
13. In a BUBL T calculation the values for what variables are given?
14. If the activity coefficient of component 1 is expressed as, $\ln \gamma_1 = x_2^2 [0.72 + 1.06x_1]$ find the infinite dilution value of component 1.
15. For species whose critical temperatures are less than the temperature of the mixture of interest, write down the equation used in place of the Raoult's law equation?
16. If a mixture of total pressure 50 psia obeys Raoult's law and a species has a vapour pressure of 20 psia, what is the DePriester K-value for the species in the mixture?



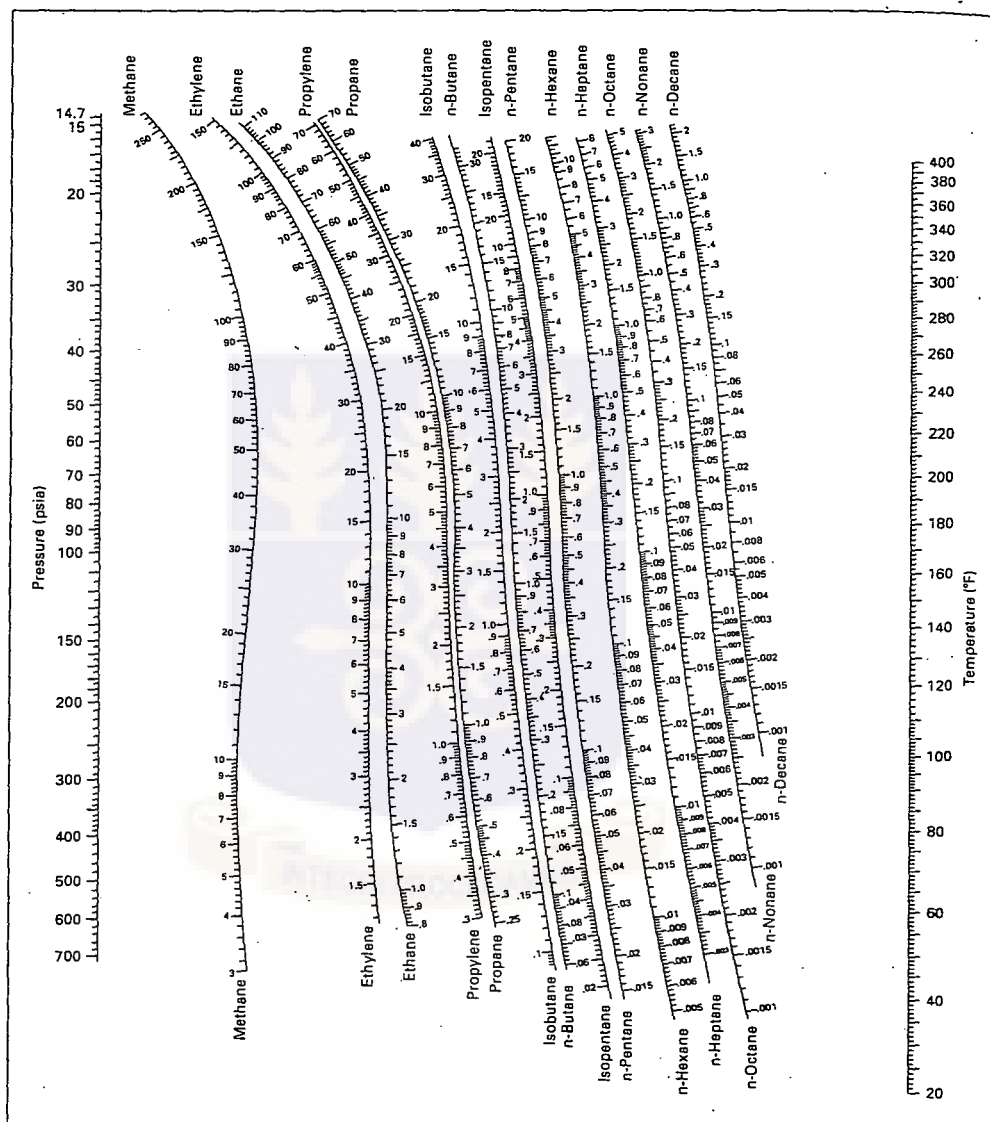


Figure 10.14: K -values for systems of light hydrocarbons. High-temperature range. (Reproduced by permission from C. L. DePriester, *Chem. Eng. Progr. Symp. Ser. No. 7*, vol. 49, p. 42, 1953.)

17. If the fugacity coefficient of the components of a binary mixture are $\hat{\phi}_1 = 0.784$, and $\hat{\phi}_2 = 0.638$ and mole fraction of component 1 is 0.4, write down an expression for the fugacity coefficient $\ln \phi$, for the mixture.

18. If the Lee-Kesler generalized correlation gives $\phi^0 = 0.627$ and $\phi^1 = 1.096$ for a pure substance with acentric factor $\omega = 0.20$, find ϕ .

19. If M represents the molar value of an extensive thermodynamic property, write down the defining expressions for the partial molar property.

20. If the second virial coefficient of a pure species $B_{11} = -35 \text{ cm}^3/\text{mol}$ at a pressure of 30 bar and temperature 200K, what is the fugacity coefficient ($R=83.14 \text{ bar/mol-K}$)

