2. (8 marks) many binary systems are known to exhibit azeotropes. A classic azeotropic mixture is provided by ethanol (1) and water (2). The azeotropic composition is approximately $x_1 = 0.89$. The boiling temperature of that mixture is approximately 79°C.

a. (4 marks) Provide an estimate for the constant A in the one-parameter Margules equation.

b. (2 marks) What is the pressure at the azeotropic composition?

c. (2 marks) Does this mixture form a maximum-boiling azeotrope or a minimum-boiling azeotrope? Explain your reasoning with at least two valid arguments to justify.

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3.4 The relative volatility of methanol to CCl_4 at point C:
a) 10.3
b) 2.3
c) 5.3
d) 3.8
e) 8.3

3.5 The vapor pressure (kPa) of methanol at 25°C:
a) 16.97
b) 15.25
c) 27.7
d) 20.07
e) 26.3

3.6 The vapor pressure (kPa) of CCl_4 at 25°C:
a) 16.97
b) 15.25
c) 27.7
d) 20.07
e) 26.3

3.7 The vapor fraction at point C is:
a) 0.25
b) 0.75
c) 0.50
d) 0.69
e) 0.31

3.8 The type of azeotrope featured in this diagram is:
a) Maximum boiling azeotrope
b) Saddle boiling azeotrope
c) No azeotrope
d) Oscillatory boiling azeotrope
e) Minimum boiling azeotrope

3.9 The activity coefficient of methanol at the azeotropic point is:
a) 1.63
b) 0.613
c) 1.82
d) 0.550
e) No azeotrope is formed

0 Raoult's law will be a good model for this system:
) True
False
Can't judge based on the given information
Good up-to-the azeotropic composition
one of these

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7. The fugacity of a component in a liquid mixture, f_i^L, is related to its activity coefficient, γ_i, by:
   a) $f_i^L = \gamma_i x_i P_i^{sat}$
   b) $f_i^L = \gamma_i x_i P$
   c) $f_i^L = \gamma_i x_i f_i^{pure}(P,T)$
   d) $f_i^L = x_i f_i^{pure}(P,T)$
   e) $f_i^L = \gamma_i P_i^{sat}$

8. The term "excess property" (e.g., M^{ex}) for a mixture refers to the difference between:
   a) The property of the actual mixture and the property of an ideal gas mixture at the same conditions.
   b) The property of the actual mixture and the property of the pure components.
   c) The property of the actual mixture and the property of an ideal solution at the same conditions.
   d) The property of the actual mixture and the property at standard conditions.
   e) The partial molar property and the pure component property.

9. The condition for vapor-liquid equilibrium (VLE) of a component i in a mixture is:
   a) $P_i^V = P_i^L$
   b) $y_i P = x_i P_i^{sat}$
   c) $f_i^V = f_i^L$
   d) $T^V = T^L$ and $P^V = P^L$
   e) $\gamma_i^V = \gamma_i^L$

10. For a binary mixture obeying the one-constant Margules equation, if A is negative, the system will exhibit:
   a) Negative deviations from Raoult's Law
   b) Positive deviations from Raoult's Law.
   c) Ideal solution behavior.
   d) Azeotrope with a maximum boiling point.
   e) Phase separation into two liquid phases.

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11. The condition for chemical equilibrium in a reacting system at constant temperature and pressure is:
   a) $\Delta G_{reaction} > 0$
   b) $\Delta G_{reaction} < 0$
   c) $\Delta G_{reaction} = 0$
   d) $\Delta H_{reaction} = 0$
   e) $\Delta S_{reaction} = 0$

12. The standard state for enthalpy changes of formation ΔH_f° for pure elements is defined as.
   a) Zero at any temperature.
   b) Zero at 298.15 K and 1 atm pressure, in their most stable form.
   c) Zero at 298.15 K and 1 bar pressure, in their most stable form.
   d) Zero at 0 K and 1 bar pressure.
   e) Equal to their enthalpy of combustion.

1. (18 marks, one mark for each question) choose the most correct answer:

1. The fundamental property that indicates the spontaneity of a process at constant temperature and pressure is the change in _____.
   a) U
   b) S
   c) A
   d) H
   e) G

2. For a pure component under ideal gas conditions, the fugacity is equal to its:
   a) Pressure
   b) Partial pressure
   c) Standard reference state pressure
   d) Saturation pressure
   e) Critical pressure

3. Which of the following statements is TRUE for an ideal solution?
   a) $\Delta H_{mix} > 0$
   b) $\Delta S_{mix} = 0$
   c) $\Delta G_{mix} = \sum x_i RT \ln x_i$
   d) $\gamma_i > 1$ for all components
   e) $\Delta V_{mix} \neq 0$

4. The residual Gibbs energy (G^R) for an ideal gas is:
   a) Zero
   b) Positive
   c) Negative
   d) Dependent on pressure only
   e) Dependent on temperature only

5. For a pure substance, at the critical point, the first and second derivatives of pressure with respe to volume (at constant temperature) are:
   a) Both positive
   b) Both negative
   c) Both zero
   d) First is zero and second is positive
   e) First is zero and second is negative

6. Which of the following would generally lead to negative deviations from Raoult's Law?
   a) Formation of an azeotrope with a maximum boiling point
   b) Strong repulsion between unlike molecules
   c) Components with significantly different molecular sizes
   d) Strong attractive interactions (e.g., hydrogen bonding) between unlike molecules
   e) Dissimilar boiling points of the components

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2. (10 marks) the system: propane (1), i-butane (2) and n-butane (3), at 300 K, has the overall composition $z = (0.5, 0.25, 0.25)$. Recovery of propane from this mixture is to be carried out by flashing the mixture in a flash drum at the prescribed temperature. If we are to operate the drum at a pressure of 500 kPa, fill in the following table and answer the short questions given. The vapor pressures for the components are given at the prescribed temperature as $p_{vap} = (990.4, 367.0, 257.0)$ kPa, respectively. Please fill in the following after you are done with your solution. NO marks will be given if no answers are provided here.

a) (1 marks) The bubble pressure of the system is $P_{bubble} =$ [ ] kPa

b) (1 marks) The dew pressure of the system is $P_{dew} =$ [ ]

c) (5 marks with table) The vapor fraction if the system can be flashed is V = [ ]

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d) (2 marks) Will distillation be a good choice for separating i-butane (2) from n-butane (3)? Justify your answer.

e) (1 marks) The hardest system to separate using ordinary distillation _____. Justify your answer.

2. (10 marks) An LPG gas cylinder is available at ambient temperature of 298.15 K, and is subjected to a pressure of 2.468 bars. The LPG is assumed to be pure n-butane. Determine the phase(s) inside the cylinder using the SRK EOS. Please answer the questions below based on your calculations. Limit yourself to three significant figures when calculating the fugacity coefficients.

2.1 The critical temperature, T_c (K) for n-butane is:

a) 425.1
b) 298.15
c) 374.1
d) 500.2
e) 450.0

2.2 The covolume, b, in SI units at the prescribed conditions is:

a) 8.0813×10^{-5}
b) 8.0813×10^{-4}
c) 8.0813×10^{-3}
d) 8.0813×10^{-2}
e) 8.0813×10^{-1}

2.3 The attractive energy parameter, a, in SI units at the prescribed conditions is:

a) 178.8
b) 17.88
c) 1.788
d) 0.1788
e) 0.01788

2.4 The reduced covolume, B, at the prescribed conditions is:

a) 0.80
b) 0.080
c) 0.0080
d) 0.00080
e) 0.000080

2.5 The reduced attractive energy parameter, A, at the prescribed conditions is:

a) 0.000718
b) 0.00718
c) 0.0718
d) 0.718
e) 7.18

2.6 The resulting cubic equation of state at the prescribed conditions is:

a) $Z^3 - Z^2 + 0.0642\,Z - 0.000580 = 0$
b) $Z^3 - Z^2 + 0.0642\,Z - 0.000580 = 0$
c) $Z^3 - Z^2 + 0.0600\,Z - 0.000580 = 0$
d) $Z^3 - Z^2 + 0.0637\,Z - 0.000578 = 0$
e) $Z^3 - Z^2 + 0.0637\,Z - 0.000812 = 0$

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3. (8 marks) Consider a chemical reaction system involving five components: A, B, C, D, and E. This system includes two independent, balanced chemical reactions occur within this system:

$$A + B \rightarrow 3C + D$$
$$B + 2D \rightarrow 3A + 4E$$

a) (2 Marks) Construct the stoichiometric matrix (ν) for this system. Ensure the components are ordered alphabetically as A, B, C, D, E in the columns.

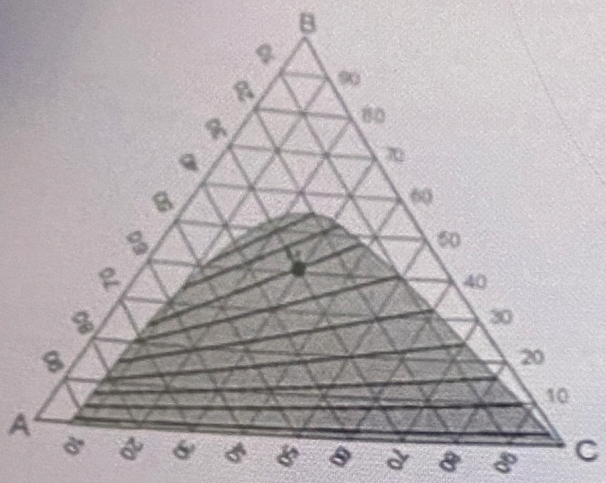
b) (2 Marks) Relate the mole fractions of components A, B, C, D, and E to the extents of reaction ξ_1 and ξ_2. The initial number of moles are $n_{A,0} = 1$ and $n_{B,0} = 1$.

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c) (2 Marks) Determine the mole fractions of components A, B, C, D, and E for $\xi_1 = 0.3$ 0.1.

d) (2 Marks) The selectivity of component C over component D is defined as the number of C divided by the number of moles of D. Determine the value for the given number of moles and extents of reaction.

4. (8 marks) the following ternary diagram for components: A, B, and C is provided. Please answer the following questions in the provided spaces.



a) (1 Mark) The solute in this system is? [ ]

b) (1 Mark) The solvent more selective towards the solute in this system is? [ ]

c) (2 Mark) An estimate for the Plait point in this system is? [ ]

d) (2 Mark) The distribution coefficient of the solute in the tie line passing through point M is? [ ]

e) (2 Mark) The fraction of C-rich phase at point M is? [ ]

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1. (10 marks, equal weight for each question) choose the most correct answer:

1. The fugacity of a pure solid at very low pressure approaches
   a) Sublimation pressure
   b) Vapor pressure
   c) System pressure
   d) Higher than system pressure
   e) Not enough data provided
2. Raoult's law will be a good approximation for which system(s) at low pressure?
   a) Benzene-heptane
   b) m-xylene – o-xylene
   c) m-xylene – p-xylenol
   d) m-xylene-heptane
   e) b and c

3. The relative volatility for a binary mixture, A, is given as $\alpha_{1,2} = 0.8$ while for another binary mixture, B, $\alpha_{1,2} = 1.50$. One can conclude that it will be easier to separate mixture B by distillation.
   a) True.
   b) False

4. The SI unit of the second virial coefficient is
   a) mol/m^3.
   b) kg/m^3.
   c) m^3/mol
   d) m^3/kg.
   e) m^3/m^3.

5. Trouton's rule estimate for the latent heat of vaporization for a compound with normal boiling point temperature of 400 K and molecular mass of 100 g/mol is _____ kJ/mol.
   a) 33256.
   b) 33.256.
   c) 332.56.
   d) 3.3256.
   e) 3325.6.

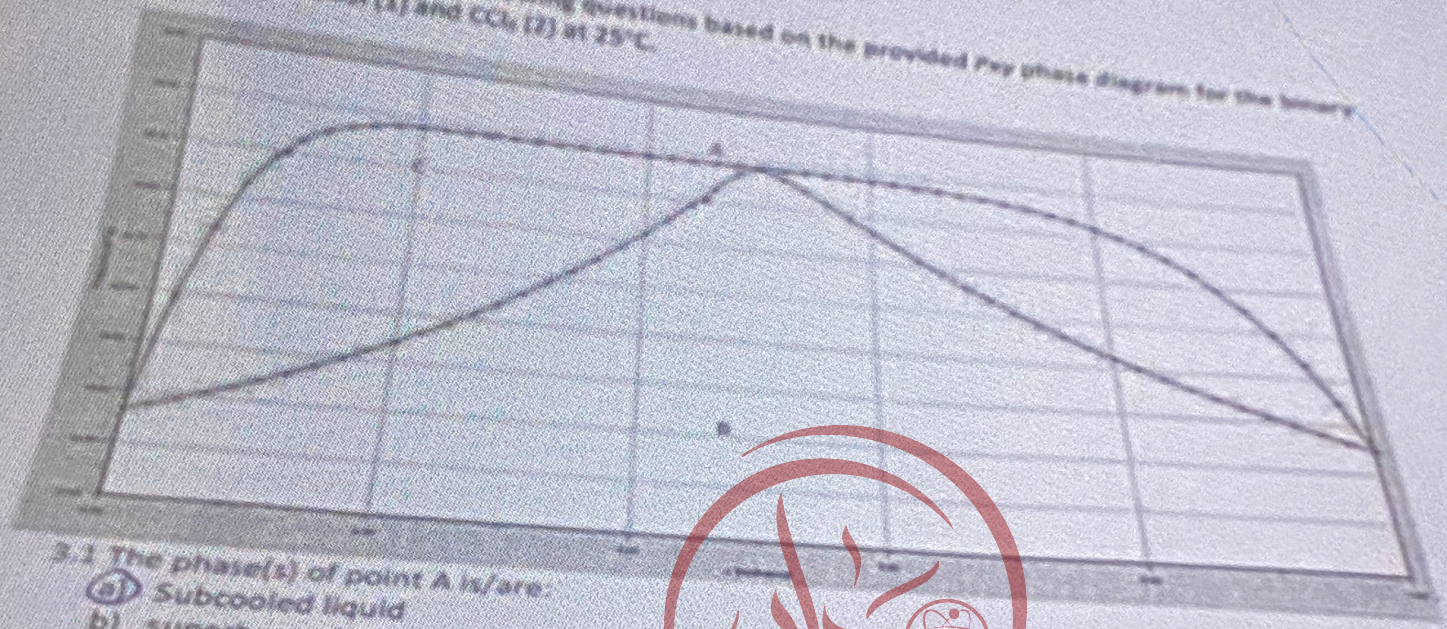
6. In the van der Waals equation, the parameter a accounts for:
   a) Finite molecular size
   b) Intermolecular attraction
   c) Molecular orientation
   d) Quantum effects
   e) Caloric imperfection

7. Which of the following is true at the critical point of a material?
   a) $f^S = f^L = f^V$.
   b) $\Delta H^{vap} = 0$.
   c) $\Delta S^{vap} = 0$.
   d) $f^S \neq f^L = f^V$ and degrees of freedom = 0.
   e) Only b and c.

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3. (10 marks) answer the following questions based on the provided Pxy phase diagram for the binary system: methanol (1) and CCl_4 (2) at 25°C.



3.1 The phase(s) of point A is/are:
a) Subcooled liquid
b) superheated vapor
c) Saturated liquid
d) Saturated vapor
e) Liquid–vapor mixture

3.2 The phase(s) of point B is/are:
a) Subcooled liquid
b) superheated vapor
c) Saturated liquid
d) Saturated vapor
e) Liquid–vapor mixture

3.3 The phase(s) of point C is/are:
a) Subcooled liquid
b) superheated vapor
c) Saturated liquid
d) Saturated vapor
e) Liquid–vapor mixture

2.7 The minimum root of the cubic equation of state at the prescribed conditions is:

a) 0.109
b) 0.00109
c) 0.000109
d) 0.0109
e) Only one real root there is no minimum

2.8 The maximum root of the cubic equation of state at the prescribed conditions is:

a) 0.09323
b) 0.9323
c) 1.09323
d) 0.0109
e) Only one real root there is no maximum

2.9 The phase(s) inside the cylinder is/are:

a) Supercritical fluid
b) Subcooled liquid
c) Superheated vapor
d) Solid
e) Liquid-vapor mixture

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13. Which thermodynamic potential is minimized at constant temperature and volume?
a) U.
b) H.
c) G.
d) A.
e) S.

14. The van der Waals equation accounts for:
a) Quantum effects.
b) Intermolecular interactions and finite molecular size.
c) Intermolecular attractions.
d) Compressibility factor being exactly 1.
e) Finite molecular size.

15. The Gibbs–Duhem equation ensures:
a) Total Gibbs free energy remains constant during mixing.
b) A relationship between the activity coefficients of mixture components.
c) Fugacity coefficients are equal in vapor and liquid phases.
d) Pressure remains constant in binary systems.
e) The chemical potential is always zero at equilibrium.

16. The Poynting correction factor accounts for:
a) The effect of high pressure on fugacity in liquid mixtures.
b) Ideal gas deviation at low pressure.
c) Heat capacity variation with temperature.
d) Non-ideal entropy changes.
e) Formation of azeotropes.

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17. The equilibrium constant expressed in terms of mole fractions for a reaction in the gas p
depends on:
a) Only T.
b) Only P.
c) Only T and x.
d) Only P and x.
e) T and P (if $\Delta n \neq 0$).

18. Consider the water–gas shift reaction: $CO + H_2O \rightleftharpoons CO_2 + H_2$, If an inert gas is added at
pressure, what is the effect on the equilibrium composition?
a) Shifts to the right.
b) Shifts to the left.
c) No shift in equilibrium composition.
d) Increases conversion of CO.
e) Decreases mole fraction of CO_2 only.