L-3/T-1/CHE Date: ~~30/04/2024~~ 20/05/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **CHE 303** (Mass Transfer I)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer **Q. No. 1** and any **TWO** from the rest.

1. (COMPULSORY)

(a) Diameter of distillation column is very important in controlling costs and has to be estimated even for preliminary designs. Explain clearly three fundamental steps to estimate the column diameter. **(7)**

(b) Flow pattern on the trays is also an important design parameter for distillation columns. With an appropriate diagram, demonstrate the selection guide of flow pattern for sieve trays. **(7)**

(c) Rationalize how the single assumption that "solutes are independent of each other" can specify more than one degree of freedom for multisolute absorption and stripping process. **(7)**

(d) When $E_0 > R_1$ the difference point is on the left-side of the right triangular equilibrium diagram; and when $R_1 > E_0$ the difference point is on the right of the diagram. What happens when $R_1 = E_0$? Answer this question using a logical argument. **(7)**

(e) Justify with proper reasoning the use of "effective equilibrium constant" in the analysis of leaching process. **(7)**

2. (a) What controls whether a column is a stripper or an absorber? **(5)**

(b) Make the necessary assumption(s) and derive the equation of operating line for an absorption process when the feed is reasonably concentrated. **(13)**

(c) A stripping tower with four equilibrium stages is being used to remove ammonia from waste water using air as the stripping agent. Operation is at 80°F and 1 atm. The inlet air is pure air, and the inlet water contains 0.02 mole fraction ammonia. The column operates at $L/V = 0.65$. Equilibrium data in mole fraction are given as $y = 1.414x$. Determine the outlet concentrations. **(17)**

3. (a) Selection of a proper solvent is very important for the development of an economical extraction system. State solvent-selection criteria for an extraction system. **(7)**

(b) We have a mixture of linoleic and oleic acids dissolved in methylcellosolve and 10% water. Feed is 0.003 wt frac linoleic acid and 0.0025 wt frac oleic acid. Feed flow rate is 1500 kg/h. A simple countercurrent extractor will be used with 750 kg/h of pure heptane as solvent. We desire a 99% recovery of the oleic acid in the extract products. The equilibrium distribution constant, $K_d$ for the given condition are 2.17 and 4.14 for linoleic and oleic acids, respectively. Find the required number of stages, N and the recovery of linoleic acid in the extract product. **(20)**

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**Contd ... Q. No. 3**

(c) Consider that the specifications of feeds and fresh solvent are fully known. Show the solution procedure using difference-point on a right triangular diagram for a two-feed extractor. **(8)**

4. (a) Would you expect stage efficiencies to be higher or lower in leaching than in liquid-liquid extraction? Explain. **(10)**

(b) A washing operation is processing 10,000 kg/h of wet solids. The liquid is essentially water with a density of 1000 kg/m$^3$, the dry solids have a density of 1500 kg/m$^3$, and the porosity is measured as $\epsilon = 0.40$. What is the flow rate of the underflow liquid in kg/h? Also state all the crucial assumptions which are required for the stage-to-stage calculation of washing process. **(10+6)**

(c) Reason why the notched weirs have better turndown characteristics than straight weirs in distillation columns. **(9)**

**SECTION – B**

There are **FOUR** questions in this section. Answer any **THREE**.

Assume reasonably if any additional data/information are required.

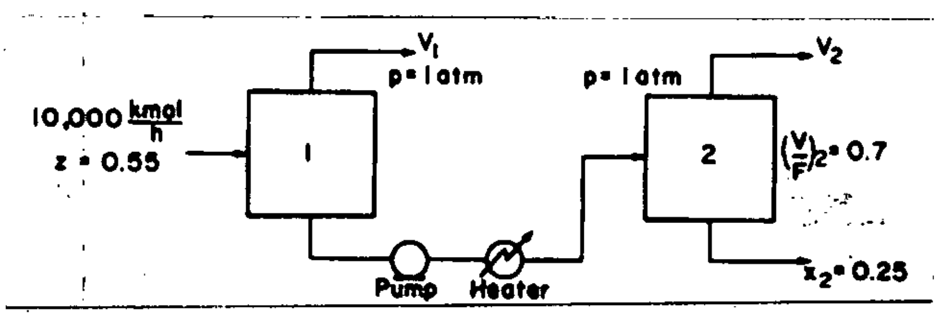
Notations indicates their usual meaning.

5. (a) Sketch the T-$_{x\text{-}y}$ diagram for Ethanol-Water system using Enthalpy-Composition Diagram attached in the question. Use at least 5 points for both T-x and T-y graph on the same graph paper. It is also required to write down the steps these you have followed to draw the graph. **(15)**

(b) Two flash distillation chambers are hooked together as shown below. Both are at 1 atm pressure. The feed to the first drum is a binary mixture of methanol and water that is 55 mol% methanol. The feed flow rate is 10,000 kmol/h. The second flash drum operates with $(V/F)_2 = 0.7$ and the liquid product composition is 25 mol% methanol. Equilibrium data are given in Table Q. 5(b). **(20)**

(i) What is the fraction vaporized in the first flash drum?

(ii) What are $y_1$, $y_2$, $x_1$, $T_1$, and $T_2$?



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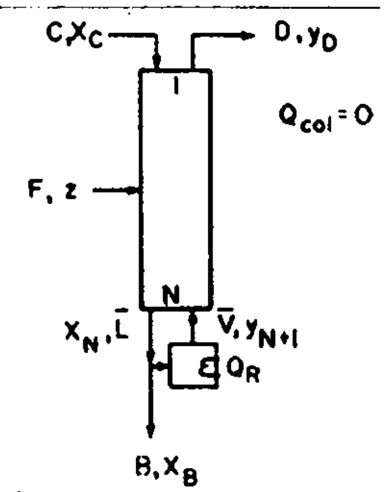
6. (a) A distillation column separating ethanol from water is shown as below. Pressure is 1 kg/cm$^2$. Instead of having a condenser, a stream of pure liquid ethanol is added directly to the column to serve as the reflux. This stream is a saturated liquid. The feed is 40 wt% ethanol and is at –20°C. Feed flow rate is 2000 kg/h. We desire a distillate concentration of 80 wt% ethanol and a bottom composition of 5 wt% ethanol. A total reboiler is used, and the boilup is a saturated vapor. The cooling stream is input at C = 1000 kg/h. Find the external boilup rate, $\overline{V}$. **(25)**

   Note: Set up the equations, solve in equation form for $\overline{V}$ for all required terms, read off all required enthalpies from the enthalpy composition diagram in Figure Q. 6(a), and then calculate a numerical answer.




   (b) Explain the concepts of total reflux and minimum reflux and how they relate to McCabe Theile diagram. **(10)**

7. (a) A mixture containing 40 mol% isopentane, 30 mol% n-hexane, and 30 mol% n-heptane is being separated. We aim to achieve a 98% recovery of n-hexane in the bottom and a 99% recovery of isopentane in the distillate. $F$ = 1000 kmol/h. Feed is a two-phase mixture that is 40% vapor. $L/D$ = 2.5. **(22)**

   (i) Find $D$ and $B$. List any required assumptions.

   (ii) Find compositions of distillate and bottom product.

   (iii) Calculate L, V, $\overline{L}$, and $\overline{V}$ assuming CMO.

   (b) What should be done if the current column is unable to achieve the desired product purity? **(13)**

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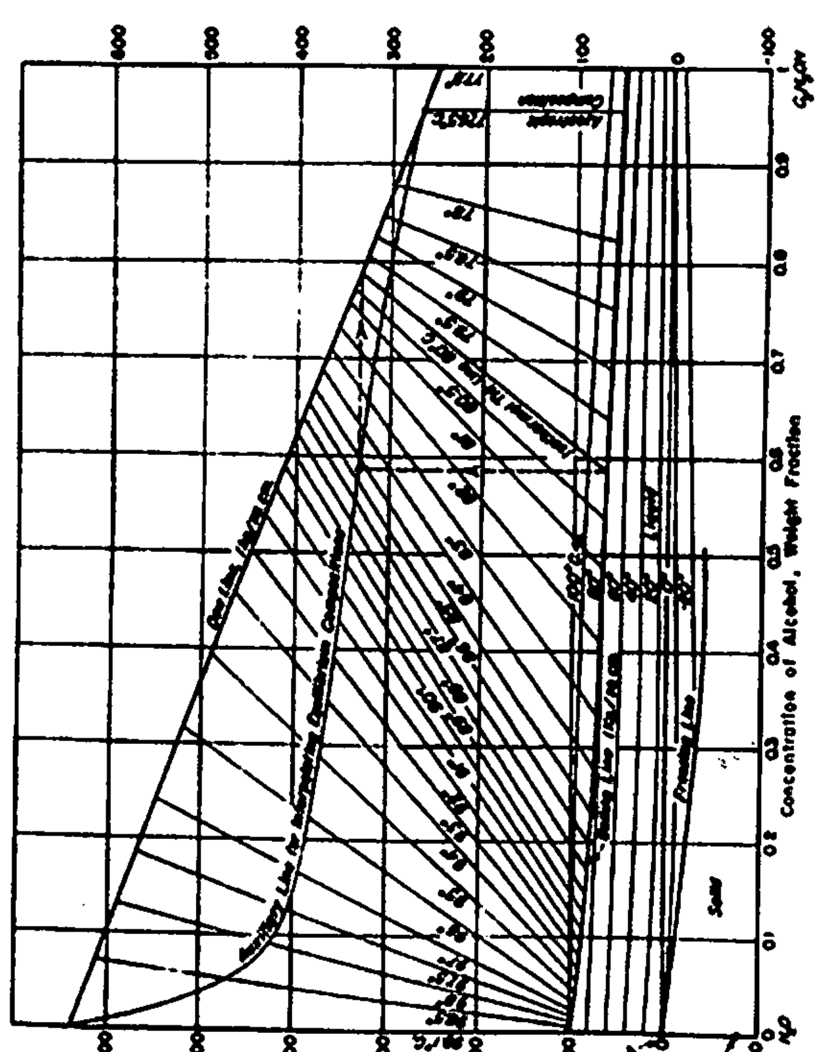
8. (a) Discuss the benefits and drawbacks of using batch distillation in contrast to continuous distillation. **(6)**

(b)Explain the variable reflux ratio method of batch distillation. **(6)**

(c) We wish to use a simple batch still (one equilibrium stage) to separate methanol from water. The feed charge to the still pot is 100 moles of a 75 mol% methanol mixture. We desire a final bottoms concentration of 55 mol% methanol. Find the amount of distillate collected, the amount of material left in the still pot, and the average concentration of distillate. Pressure is 1 atm. Equilibrium data are given in Table 8(c). **(23)**

Q 6(a)



**Enthalpy-composition diagram for ethanol-water at a pressure of 1 kg/cm²**

*(Bosnjakovic, Technische Thermodynamik, T. Steinkopff, Leipzig, 1935)*

Q 5(a)

Figure for Q 5(a) and Q 6(a)

*Table Q 5(b) and Question 8(C) Vapor-liquid equilibrium data for methanol water (p = 1 atm) (mol%)*

| *Methanol Liquid* | *Methanol Vapor* | *Temp., °C* |
|---|---|---|
| 0 | 0 | 100 |
| 2.0 | 13.4 | 96.4 |
| 4.0 | 23.0 | 93.5 |
| 6.0 | 30.4 | 91.2 |
| 8.0 | 36.5 | 89.3 |
| 10.0 | 41.8 | 87.7 |
| 15.0 | 51.7 | 84.4 |
| 20.0 | 57.9 | 81.7 |
| 30.0 | 66.5 | 78.0 |
| 40.0 | 72.9 | 75.3 |
| 50.0 | 77.9 | 73.1 |
| 60.0 | 82.5 | 71.2 |
| 70.0 | 87.0 | 69.3 |
| 80.0 | 91.5 | 67.6 |
| 90.0 | 95.8 | 66.0 |
| 95.0 | 97.9 | 65.0 |
| 100.0 | 100.0 | 64.5 |

Source: Perry et al. (1963), p. 13-5.

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub : **CHE 313** (Solution Thermodynamics)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

## SECTION – A

There are **FOUR** questions in this section. Answer Question No. 1 is Compulsory and carries 45 marks. Answer any **TWO** questions from the rest of the 3 questions.

1. Answer the questions below. Clarify your answers with **adequate reasoning**. Answering without any reasoning will bear zero marks.

(i) Explain what will happen if there is no stability to a vapor-liquid system in equilibrium. You can use the stability criterion applicable to this scenario to clarify your answer. **(7)**

(ii) "After adsorption of molecules on a solid surface, the equilibrium is maintained between the adsorbed molecules and vapor phase" – Is it true or, false? Give reasons to your answer. **(7)**

(iii) Liquefaction converts only a small fraction of a gas to liquid through Linde process. Why is it still relevant to use this method in commercial scale? How can you overcome the limitation? Provide reason(s) to your answer. **(7)**

(iv) Derive the simplified equation for solid-vapor equilibrium applicable under high pressure scenario. Give an example of an application where this equation could be used. **(8)**

(v) Illustrate the basic mechanism (with reactions) for an alkaline fuel cell. How can thermodynamic equilibrium provide effective estimation of fuel cell efficiency? Explain. **(10)**

(vi) "Despite the dependence on temperature, K is called the equilibrium constant for a reaction" – using the expression for its temperature dependence (see formula sheet), asses this statement.

2. (a) Describe the general method of liquefaction. Provide a schematic to differentiate between Linde and Claude Process. **(5+10=15)**

(b) Describe the vapor-liquid compression cycle with a schematic of the process. Explain different steps of the process using *T-S* and *lnP-H* diagrams. **(8+7=15)**

3. (a) The equilibrium composition at 1000 K and 1 bar of a gas-phase system containing the species C, CO and $CO_2$ are to be determined. In the initial unreacted state, there are 1 mol C and 1 mol $CO_2$ present. (Reaction: $C+CO_2 = 2CO$).

Values of $\Delta G_f^0$ at 1000 K are:

$\Delta G_{fco}^0 = -200.24\ kJ/mol$ at $\Delta G_{fco_2}^0 = -395.79$ kJ/mol

Based on this data, estimate the equilibrium concentration of the components and $\lambda_k$ values. **(20)**

[Hint: see formula sheet]

Contd .......... P/2

(b) Natural gas, assuming pure methane, is liquified in a simple Linde process. Compression is to 60 bar and precooling is to 300 K. The separator is maintained at a pressure of 1 bar, and un-liquefied gas at this pressure leaves the cooler at 295 K. What fraction of the gas is liquefied in the process and what is the enthalpy of the high-pressure gas entering the throttle valve?

At 300 K and 60 bar, Enthalpy of superheated methane = 1140 kJ/kg

At 295 K and 1 bar, Enthalpy of superheated methane = 1188.9 kJ/kg

At 1 bar pressure, under saturated condition of methane, $T^{sat}$ = 111.45 K, saturated liquid enthalpy = 285.4 kJ/kg, and saturated vapor enthalpy = 796.9 kJ/kg

4. (a) $K = \frac{x_1 \gamma_1 f_1^l P^0}{(y_2 \hat{\varphi}_2 P)(x_3 \gamma_3 f_3^l)}$

This is an expression for a multiphase reaction equilibrium constant. Assuming the expression, answer the following questions: **(5+10=15)**

(i) Identify the phase of the component 1, 2 and 3 from the equation. Give reasons to your identification.

(ii) Make possible assumptions that could be applied to simplify and solve the equation for K. Clearly mention the circumstances when these assumptions will be applicable.

(b) 1 mol CO and 2 mol $H_2O$ are being reacted to produce $CO_2$ and $H_2$ in presence of 2 mol $N_2$ in the system. The reaction is taking place at 1100 K and 2 ba. Under ideal condition **(12+3=15)**

(i) Calculate the extent of reaction if the value of K is 1.1 under this condition.

(ii) Predict the outcome if the pressure is doubled for this system.

## SECTION - B

There are **FOUR** questions in this section. Answer any **FOUR** questions.

Symbols have their usual meanings.

5. (a) Explain the term "retrograde condensation". Discuss its applicability in the operation of deep natural gas wells. **(10)**

(b) A binary system of species 1 and 2 consists of vapor and liquid phases in equilibrium at temperature T. The overall mole fraction of species 1 in the system is $z_1 = 0.65$. **(25)**

At temperature T

$$ln\gamma_1 = 0.67x_2^2 \qquad ln\gamma_2 = 0.67x_1^2$$
$$p_1^{sat} = 32.27\ kPa \quad p_2^{sat} = 73.14\ kPa$$

(i) Over what range of pressure can this system exist as two phases at given T and $z_1$.

(ii) For a liquid mole fraction $x_1 = 0.75$, what is the pressure P and what molar fraction v of the system is vapor?

(iii) Show whether or not the system exhibits an azeotrope.

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6. (a) Define partial molar properties and show that for constant P and T. **(15)**

$$\sum x_i d\bar{M}_i = 0$$

(b) "For a pure species coexisting liquid and vapor phases are in equilibrium when they have same temperature and fugacity" True/False – Explain your answer. **(5)**

(c) Show that for pure liquid $f_i = p_i^{sat} exp \frac{B_{ii} p_i^{sat} + v_i^l (p - p_i^{sat})}{RT}$ **(15)**

7. (a) VLE data for methyl tert-butyle ether(1) dichloromethane (2) at 308.15 k are as follows: **(35)**

| P/kPa | $x_1$ | $y_1$ | P/kPa | $x_1$ | $y_1$ |
|---|---|---|---|---|---|
| 85.2 | 0.00 | 0.00 | 53.6 | 0.674 | 0.588 |
| 82.2 | 0.058 | 0.025 | 50.4 | 0.847 | 0.824 |
| 76.7 | 0.166 | 0.08 | 49.7 | 0.953 | 0.950 |
| 68 | 0.332 | 0.197 | 49.62 | 1.00 | 1.00 |
| 59.6 | 0.504 | 0.368 | | | |

The data are well co-related by there parameter Margules equation

$$\frac{G^E}{R_T} = (A_{21}x_1 + A_{12}x_2 - cx_1x_2)x_1x_2$$

Implied by this equation are the expressions:

$$ln\gamma_1 = x_2^2[(A_{12} + 2(A_{21} - A_{12} - c)x_1 + 3cx_1^2]$$

(a) Find the values of parameters $A_{12}$, $A_{21}$ and C that provide the best fit of $G^E/RT$ to the data.

(b) Prepare a plot of $ln\gamma_1$, $ln\gamma_2$ and $G^E/x_1x_2RT$ $vs\ x_1$ showing both the experimental and calculated values

(c) Prepare a P-x-y diagram.

8. (a) Th excess enthalpy for a liquid mixture of species 1 and 2 at fixed T and P is represented by the equation $H^E = x_1x_2(40x_1 + 20x_2)$ **(15)**

where $H^E$ is in J/mol. Determine expressions for $\bar{H}_1^E$ and $\bar{H}_2^E$ as function of $x_1$.

(b) If the molar density of a binary mixture is given by the empirical **(10)**

$$\rho = a_0 + a_1x_1 + a_2x_1^2$$

Find the $\bar{V}_1$ and $\bar{V}_2$

(c) Show that for pure liquid $\underset{x_1 \to 0}{Lt} \frac{G^E}{x_1x_2RT} = ln\gamma_1^\infty$ **(10)**

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List of Formulas

ChE-313.

Solution Thermodynamics

1. $d(nG) = (nV)dP - (nS)dT$
2. $d(nG) = (nV)dP - (nS)dT + \sum_i^n \mu_i \, dn_i$
3. $d(nG) = [\partial(nG)/\partial P]_{T,n}\, dP + [\partial(nG)/\partial T]_{P,n}\, dT + [\partial(nG)/\partial n_i]_{P,T,n_j}\, dn_i$
4. $H = G - T\left(\frac{\partial G}{\partial T}\right)_{P,x}$
5. For equilibrium between two phase $\alpha$ and $\beta$

   $\sum i\, \mu_i^\alpha dn_i^\alpha + \sum i\, \mu_i^\beta dn_i^\beta = 0$
6. Partial Molar Property, $\bar{M}_i = \left[\frac{\partial(nM)}{\partial n_i}\right]_{T,P,n_j}$
7. Gibbs-Duhem equation:

$$\left(\frac{\partial M}{\partial P}\right)_{T,x} dP + \left(\frac{\partial M}{\partial T}\right)_{P,x} dT - \sum_i x_i \, dM_i = 0$$

8. $\sum_i x_i \, dM_i = 0$ at constant T and P
9. $\bar{M}_1 = M + x_2 \frac{dM}{dx_1}$ and $\bar{M}_1 = M + x_1 \frac{dM}{dx_1}$
10. $\mu_i^{ig} \equiv \bar{G}_i^{ig} = \Gamma_i(T) + RT \ln(y_i P)$
11. $G^{ig} \equiv \sum_i y_i \Gamma_i(T) + RT \sum_i y_i \ln(y_i P)$
12. $G_i \equiv \Gamma_i(T) + RT \ln f_i$
13. $G_i - G_i^{ig} = RT \ln\left(\frac{f_i}{P}\right)$
14. Residual Gibbs free energy, $G_i^R = RT \ln\left(\frac{f_i}{P}\right) = RT \ln \phi_i$
15. Fugacity Coefficient, $\phi_i = \frac{f_i}{P}$
16. Phase rule, $F = 2 - \pi + N$
17. Criteria of stability for mixing,

   $(dG_t)_{T,P} \le 0$ and $\frac{d(\Delta G/RT)}{dx_1} > 0$

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$$\frac{d(\Delta G^E/RT)}{dx_1} > -\frac{1}{x_1 x_2}$$

18. Excess Gibbs Free Energy, $\bar{G}_i^E = RT \ln \gamma_i$.

19. Activity Coefficient, $\gamma_i = \frac{\hat{f}_i}{x_i f_i}$

20. $\frac{G^E}{RT} = \sum_i x_i \ln \gamma_i$

21. $d\left(\frac{nG^E}{RT}\right) = \frac{nV^E}{RT} dP + \frac{nH^E}{RT^2} dT + \sum_i \ln \gamma_i \, dn_i$

22. Gamma phi formulation, $y_i \hat{\emptyset}_i^v P = x_i \gamma_i f_i^l$

23. $f_i^l = \emptyset_i^{sat} P_i^{sat} \exp \frac{V_i^l(P-P_i^{sat})}{RT}$

24. $\Phi_i = \frac{\hat{\emptyset}_i^v}{\emptyset_i^{sat}} \exp\left[-\frac{V_i^l(P-P_i^{sat})}{RT}\right]$

25. Antoine equation, $\ln P_i^{sat} = A_i - \frac{B_i}{T+C_i}$

26. Roult's Law, $y_i P = x_i P_i^{sat}$

27. Modified Roult's Law, $y_i P = x_i \gamma_i P_i^{sat}$

28. Henry's Law $f_i^l = x_i H_i$

29. $x_1 \frac{d\ln \hat{f}_1^l}{dx_1} + x_2 \frac{d\ln \hat{f}_2^l}{dx_1} = 0 \ (at\ constant\ T\ and\ P)$

**30. Redlich/Kister Expansion:**

$Y = A_0 + \sum_{n=1}^{a} A_n z^n$

31. $\frac{\bar{G}_1^E}{RT} = \frac{G^E}{RT} + x_2 \frac{d(G^E/RT)}{dx_1}$

32. $\frac{\bar{G}_2^E}{RT} = \frac{G^E}{RT} - x_1 \frac{d(G^E/RT)}{dx_1}$

**33. Margules equation:**

$\ln\gamma_1 = x_2^2[A_{12} + 2(A_{21} - A_{12})x_1]$

$\ln\gamma_2 = x_1^2[A_{21} + 2(A_{12} - A_{21})x_2]$

***At infinite dilution,*** $\ln \gamma_1^\infty = A_{12}$ *and* $\ln \gamma_2^\infty = A_{21}$

**34. Van Laar Equation:**

$$\frac{x_1 x_2}{G^E/RT} = A' + B'(x_1 - x_2) = A' + B'(2x_1 - 1)$$

$$\frac{G^E}{x_1x_2RT} = \frac{A'_{12}A'_{21}}{A'_{12}x_1 + A'_{21}x_2}$$

$$ln\gamma_1 = A'_{12}\left(1 + \frac{A'_{12}x_1}{A'_{21}x_2}\right)^{-2} \quad and \; ln\gamma_2 = A'_{21}\left(1 + \frac{A'_{21}x_2}{A'_{12}x_1}\right)^{-2}$$

35. **Wilson Equation:**

$$ln\gamma_1 = -\ln(x_1 + x_2\Lambda_{12}) + x_2\left(\frac{\Lambda_{12}}{x_1 + x_2\Lambda_{12}} - \frac{\Lambda_{21}}{x_2 + x_1\Lambda_{21}}\right)$$

$$ln\gamma_2 = -\ln(x_2 + x_1\Lambda_{21}) - x_1\left(\frac{\Lambda_{12}}{x_1 + x_2\Lambda_{12}} - \frac{\Lambda_{21}}{x_2 + x_1\Lambda_{21}}\right)$$

At infinite dilution,

$\ln\gamma_1^{\infty} = -\ln\Lambda_{12} + 1 - \Lambda_{21}$ and $\ln\gamma_2^{\infty} = -\ln\Lambda_{21} + 1 - \Lambda_{12}$

36. **NRTL Equation:**

$$\frac{G^E}{x_1x_2RT} = \frac{G_{21}\tau_{21}}{x_1+x_2G_{12}} + \frac{G_{12}\tau_{12}}{x_2+x_1G_{21}}$$

$$ln\gamma_1 = x_2^2\left[\tau_{21}\left(\frac{G_{21}}{x_1+x_2G_{21}}\right)^2 + \frac{G_{12}\tau_{12}}{(x_2+x_1G_{21})\text{^}2}\right]$$

$$ln\gamma_2 = x_1^2\left[\tau_{12}\left(\frac{G_{12}}{x_2+x_1G_{12}}\right)^2 + \frac{G_{21}\tau_{21}}{(x_1+x_1G_{21})\text{^}2}\right]$$

37. **Multicomponent Systems**

$$\frac{G^E}{RT} = -\sum_i x_i \ln\left(\sum_j x_j\Lambda_{ij}\right)$$

$$ln\gamma_i = 1 - \ln\left(\sum_j x_j\Lambda_{ij}\right) - \sum_k \frac{x_k\Lambda_{ki}}{\sum_j x_j\Lambda_{kj}}$$

$$\Lambda_{ij} = \frac{V_j}{V_i}\exp\frac{-a_{ij}}{RT}$$

38. **Residual Properties by cubic Equations of State**

$$\frac{G^R}{RT} = Z - 1 - \ln(Z - \beta) - qI$$

39. **Flash Calculation**

$$y_i = \frac{z_iK_i}{1+V(K_i-1)}$$

$$x_i = \frac{z_i}{1+v(K_i-1)}$$

$$F = \sum_i \frac{z_i(K_i-1)}{1+v(K_i-1)}$$

40. **VLE from Cubic Equation of State**

$y_i \hat{\phi}_i^v = x_i \hat{\phi}_i^l$

41. **Mixture of VLE**

$Z^v = 1 + \beta^v - q^v \beta^v \frac{Z^v - \beta^v}{(Z^v + \varepsilon\beta^v)(Z^v + \sigma\beta^v)}$

$Z^l = \beta^l + (Z^l + \varepsilon\beta^l)(Z^l + \sigma\beta^l)\left(\frac{1 + \beta^l - Z^l}{q^l \beta^l}\right)$

42. **Chemical Reaction Equilibrium**

$\int_{n_0}^{n_i} dn_i = \vartheta_i \int_0^{\varepsilon} d\varepsilon$

$y_i = \frac{n_i}{n} = \frac{n_{i0} + \vartheta_i \varepsilon}{n_0 + \vartheta\varepsilon}$ (for single reaction)

$y_i = \frac{n_i}{n} = \frac{n_{i0} + \sum_j \vartheta_{i,j}\varepsilon_j}{n_0 + \sum_j \vartheta_j \varepsilon_j}$ (for multi-reaction)

43. Equilibrium Constant

$ln \prod_i \left(\frac{\hat{f}_i}{f_i^o}\right)^{\vartheta_i} = \frac{-\sum_i \vartheta_i G_i^o}{RT} = lnK = \frac{-\Delta G^o}{RT}$

$\frac{dlnk}{dT} = \frac{\Delta H^o}{RT^2}$

$K = K_0 K_1 K_2$

For gas phase reaction

$\prod_i (y_i \hat{\phi}_i)^{\vartheta_i} = \left(\frac{P}{P^0}\right)^{-\vartheta} K$

$\Delta G_{fi}^0 + RTln\left(\frac{y_i \hat{\phi}_i P}{P^0}\right) + \sum_k \lambda_k a_{ik} = 0$

44. Phase rule for reactive system, F=2-π+N-r

45. $E = \frac{-W_{elect}}{2F}$

46. **Criteria of Stability and Equilibrium for LLE**

$\frac{dln\gamma_i}{dx_i} > -\frac{1}{x_i}$ (constant T and P)

$\frac{d\hat{f}_1}{dx_1} > 0 \; and \; \frac{d\mu_1}{dx_1} > 0$ (constant T and P)

$\frac{dy_1}{dx_1} > 0$ when pressure effect is negligible

$\frac{1}{P}\frac{dP}{dx_1} = \frac{(y_1 - x_1)}{y_1 x_1}\frac{dy_1}{dx_1}$ when pressure effect is considered

$\frac{dP}{dx_1} = 0$ in azeotrope

$ln\frac{\gamma_1^{\alpha}}{\gamma_1^{\beta}} = ln\frac{x_1^{\beta}}{x_1^{\alpha}}$

47. **Criteria of Stability and Equilibrium for SVE**

$y_i = \frac{P_1^{sat}}{P}\frac{\phi_1^{sat}}{\hat{\phi}_1}\exp\frac{V_1^s(P - P_1^{sat})}{RT}$

48. **Adsorption**

$d(nG) = (na)d\Pi - (nS)dT + \sum_i^n \mu_i\, dn_i$

$SdT - ad\Pi + \sum_i^n n_i\, d\mu_i = 0$

$-\frac{a}{RT}d\Pi + dlnP + \sum_i x_i dln y_i = 0$

49. **Refrigeration:**

Network in Carnot Refrigeration Cycle, $W = -(Q_c + Q_H)$

Coefficient of Performance, $\omega = \frac{Q_c}{W} = \frac{T_c - T_h}{T_c}$

Coefficient of Performance of vapor compression cycle, $\omega = \frac{H_2 - H_1}{H_3 - H_2}$

Mass flow rate, $\dot{m} = \frac{\dot{Q}_c}{H_2 - H_1}$

For absorption refrigeration cycle, $W = \frac{T_s - T_c}{T_c} Q_c$ and $\frac{Q_h}{Q_c} = \frac{T_h}{T_h - T_s} \times \frac{T_s - T_c}{T_c}$

For liquefaction process, $z = \frac{x(H_{12} - H_5) + H_4 - H_{15}}{H_9 - H_{15}}$

And $z = \frac{H_4 - H_{15}}{H_9 - H_{15}}$

L-3/T-1/CHE Date: ~~05/05/2024~~ 26/5/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **CHE 431** (Food Preservation and Processing)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Discuss in detail the role of various factors in the spoilage of foods. **(10)**

   (b) How do native enzymes cause spoilage of food? How can the spoilage be prevented or minimized? **(15)**

   (c) Classify the various foods with appropriate examples on the basis of their ease of spoilage. **(10)**

2. (a) Write short notes on the following topics: **(10×2)**

   (i) Different sorting methods used in food industry; and

   (ii) Dry cleaning methods

   (b) Briefly explain Nitrogen Cycle with respect to the roles of microorganisms. **(15)**

3. (a) Briefly explain the principles of food preservation. **(7)**

   (b) Discuss in detail the principles of thermal destruction of microorganisms explaining the term D-value. **(15)**

   (c) What are the factors affecting heat resistance of microorganisms? Briefly explain with appropriate examples. **(13)**

4. (a) Briefly explains the factors of relevance in the control of food drying. **(10)**

   (b) Write a short note on the different kinds of drying equipment used in food industry. **(13)**

   (c)Briefly explain refrigeration principle and requirements of freezing foods. **(12)**

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. (a) Food diseases can be deficiency type or diseases of affluence. Describe and contrast one example of each. **(10)**

   (b) Discuss the concept of water activity in context of food spoilage and food preservation. What are the zones of reaction in a moisture content-water activity relationship, and how can you use this information for food preservation? **(18)**

   (c)Briefly describe how you would test water content in food samples? **(7)**

6. (a) What is the A, H-B system and how is it related to a nutritional quality in sugars? How are fructose and sucrose similar and how are they different from each other? **(10)**

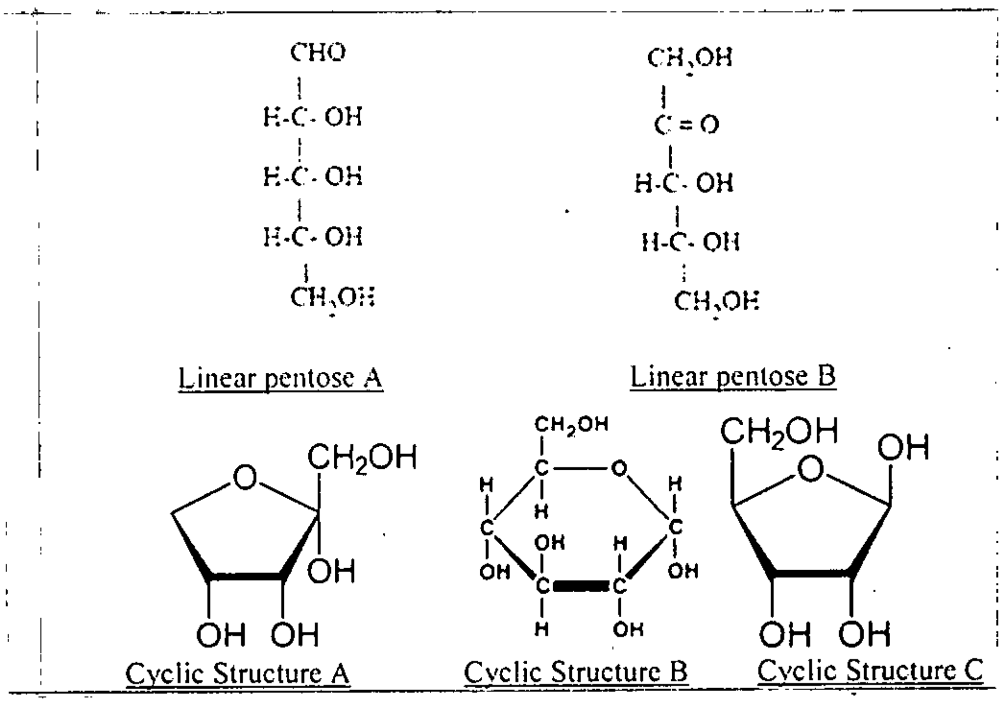
   (b) Illustrate the schematic structure of any polysachharide, using a diagram. Comment on the stability of the molecule based on your structure.

Contd .......... P/2

**CHE 431**

(c) Discuss any 2 non-starch polysachharides, and how they are used for food related applications. **(10)**

(d) Below are linear and cyclic representations of two pentoses, discuss the differences between them and pick the most probable cyclic structure that would be formed by Linear Structure A. **(5)**




7. (a) "Change of taste and texture in proteins is due to chemical reactions to modify them or their constituent peptides or amino acids." Justify this statement with 4 suitable examples. **(12)**

   (b) State the type of secondary structure in the following proteins and elucidate the role of these structures for the flavor or function of the food associated with them. Be sure to include the name of a specific food item for each. **(8)**

   (i) Collagen
   (ii) Gluten

   (c) What is rigor mortis? Discuss its significance for preservation, storage and cooking of meat. **(10+5)**
   Is there an equivalent phenomenon in the processing of fish? What, if any?

8. (a) What are the names and functions of some useful microorganisms to human? (Name and describe 2) **(13)**

   (b) How do the following enzymes contribute towards food processing? **(12)**

   (i) Lipoxynase
   (ii) Peroxidase
   (iii) Amylase
   (iv) Phenolase

   (c) What are some food borne illnesses and what are the microorganisms associated with the diseases? Name at least five. **(10)**

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L-3/T-1/CHE　　　　　　　　　　　　　　　　　　　　　　　　Date: ~~05/05/2024~~ 26/5/24

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **MATH 327** (Multivariable Statistical Analysis and Complex Analysis)

Full Marks: 210　　　　　　　　　　Time: 3 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Prove the triangle inequalities **(12)**

   (i) $|z_1 + z_2| \le |z_1| + |z_2|$

   (ii) $|z_1 - z_2| \ge ||z_1| - |z_2||$

   (b) Find the roots of the equation $z^4 + 8 + 8\sqrt{3}i = 0$ in rectangular coordinates, exhibit them geometrically, and point out which is the principal root. **(12)**

   (c) Find four roots of the equation $z^4 + 4 = 0$ and use them factorize $z^4 + 4$ into quadratic factors with real coefficients. **(11)**

2. (a) Define analytic function and harmonic function. Show that the function $f(z) = |z|^2$ is differentiable only at $z = 0$ and nowhere else. **(17)**

   (b) Show that $u(x, y) = 2x - x^3 + 3xy^2$ is harmonic and find a harmonic conjugate $v(x, y)$. Then express $f(z) = u + iv$ in terms of $z$. **(18)**

3. (a) Evaluate $\int_C \bar{z}dz$ from $z = 0$ to $z = 4 + 2i$ along the curve $C$ given by (i) $z = t^2 + it$; (ii) the line from $z = 0$ to $z = 2i$ and then from $z = 2i$ to $z = 4 + 2i$. **(18)**

   (b) State Cauchy's Integral formula and use Cauchy's Integral formula to evaluate the integral $\int_C \frac{z+1}{z^2 - 2z} dz$, where $C$ the circle $|z| = 3$ described in the positive sense. **(17)**

4. (a) Expand $f(z) = \frac{1}{z(z-2)}$ in a Laurent series valid for (i) $1 < |z| < 2$, (ii) $|z| > 2$. **(18)**

   (b) Using residue theorem find the value of the integral $\int_C \frac{3z^3 + 2}{(z-1)(z^2+9)} dz$, taken counterclockwise around the circle $C$ with equation $|z| = 4$ described in the positive sense. **(17)**

Contd .......... P/2

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. Evaluate the following integrals by contour integration:

(a) $\int_0^{2\pi} \frac{\sin^2\theta}{5-4\cos\theta} d\theta$ **(15)**

(b) $\int_{-\infty}^{\infty} \frac{1}{x^4+1} dx$ **(20)**

6. (a) Let $X_{n\times p}$ be a data matrix containing $n$ observations and $p$ features. Derive the formulas of mean vector, covariance matrix, correlation matrix for the data matrix $X_{n\times p}$. What is the relationship between covariance and correlation? **(8)**

(b) Calculate mean vector, covariance matrix, correlation matrix for the data matrix below. Interpret the correlation matrix graphically. **(20)**

| $x_1$ | $x_2$ |
|---|---|
| 3 | 5 |
| 4 | 5.5 |
| 2 | 4 |
| 6 | 7 |
| 8 | 10 |
| 2 | 5 |
| 5 | 7.5 |

(c) What is the multivariate distribution, and how does it differ from the univariate normal distribution? **(7)**

7. (a) Derive the probability density function for the bivariate normal distribution. **(10)**

(b) Describe the method of least squares and how it is utilized to estimate parameter, $\hat{\beta} = \left(X^T X\right)^{-1} X^T Y$ in multivariate regression. **(10)**

(c) Suppose you have the following dataset with one response variable (Exam Score) and two predictor variables (Study Hours and Facebooking Hours). Fit a multiple linear regression model for this dataset. Interpret your results. **(15)**

| Study Hours | Facebooking Hours | Exam Score |
|---|---|---|
| 60 | 22 | 140 |
| 62 | 25 | 155 |
| 67 | 24 | 159 |
| 70 | 20 | 179 |
| 71 | 15 | 192 |
| 72 | 14 | 200 |
| 75 | 14 | 212 |
| 78 | 11 | 215 |

Contd .......... P/3

8. (a) Compare the assumptions of ANOVA and MANOVA. How are they similar, and how do they differ? **(7)**

(b) What is principal component analysis (PCA), and what is its primary purpose in data analysis? **(8)**

(c) Calculate the principal components for the following dataset: **(20)**

| feature 1 | feature 2 |
|---|---|
| 2.5 | 2.4 |
| 0.5 | 0.7 |
| 2.2 | 2.9 |
| 1.9 | 2.2 |
| 3.1 | 3 |

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