Department of Petrochemical Engineering

Subject: Engineering Thermodynamics (BTPCC401) (Sample Question Bank)

Semester: IV

Unit I

(1) A househusband is cooking beef stew for his family in a pan that is i) uncovered, ii) covered with a lid and iii) covered with a heavy lid . For which case the cooking time will be shortest? Why? What about the other two?

(2) A system comprised of chloroform,1,4-dioxane and ethanol exists as a two-phase vapor/liquid system at 50°C and 55 kPa. It is found, after the addition of some pure ethanol, that the system can be returned to two-phase equilibrium at the initial T and P. In what respect has the system changed and in what respect has it not changed?

(3) Briefly elaborate on concept of equilibrium. An oil water emulsion is in equilibrium with its vapor. How many degree of freedom system has? Calculate.

(4) Heat in the amount of 7.5 kJ is added to a close system while its internal energy decreases by 12 kJ. How much energy is transferred as work ? For a process causing a same change of state but for which the work is zero , how much heat is transferred?

(5) A rigid tank contains 10 kg of air at 200kPa & 27 ^{0}C. The air is now heated until its pressure doubles. Determine the volume of tank & the amount of Heat Transfer.
(C_v air = 0.733 kJ/kg K .)

(6) For a steady flow through a heat exchanger at approximately atmospheric pressure, what
is the final temperature when heat in the amount of 2500 kJ is added to 15 mol of 1 butane initially at 533.15 K? (Solve by iterative method)

$$\frac{C_p^{ig}}{R} = 1.967 + 0.0316\,T - 9.873 \times 10^{-6}\,T^2$$

where T is in K .

(7) Saturated water vapor, i.e., steam, is commonly used as a heat source in heat exchanger applications. Why saturated vapour? Why saturated water vapour? In plant of any reasonable size, several varieties of saturated steam are commonly available; for example, saturated steam at 4.5, 9, 17,and 33 bar. But the higher the pressure the lower the useful

energy content (Why?), and the greater the unit cost. Why then is higher-pressure steam used?

(7) Natural gas (assume pure methane) is delivered to a city via pipeline at a volumetric rate of 4 normal Mm^3 per day. Average delivery conditions are 283.25 K and 20.7 bar.

Determine :

i)The volumetric delivery rate in actual m^3 per day.

ii) The molar delivery rate in kmol per hr.

iii)The gas velocity at delivery conditions in m/s

The pipe is 600mm heavy duty steel with an inside diameter of 575mm. Normal conditions are 273.25 K and 1 atm.

(8) Estimate the volume change of vaporization for ammonia at 20^0 C.At this temperature the vapor pressure of ammonia is 857 kPa.

Data: $\omega = 0.253$, $T_C = 405.7$ K, $P_C = 112.80$ bar , $Z_C = 0.242$, $V_C = 72.5$ cm^3/mole.

(9) A pressure vessel contains liquid water and water vapor in equilibrium at 450.15K .The total mass of liquid and vapor is 1.36 kg.If the volume of the vapor is 50 time s the volume of liquid ,what is the total enthalpy content of the vessel?

10)The temperature in a pressure cooker during cooking at sea level is measured to be 120^0 C .Determine the absolute pressure inside the cooker in psia and in atm. Would you modify your answer if the place were at a higher elevation?

11)Liquids that boil at relatively low temperature are often stored as liquid under their vapor pressure, which at ambient temperature can be quite large. Thus , n –butane stored as a liquid vapor system is at a pressure of 2.581 bar for a temperature of 27^0C . Large scale storage (>50 m^3) of this kind is sometimes done in spherical tanks. Suggest two reasons , why?

12) Define the following :

i) Process ii) Path iii) Property & its type.

An astronaut weigh 730 N in Houston, Texas, where the local acceleration of gravity $g = 9.792$ m/s^2 . What are the astronaut's mass and weight on the moon, where $g = 1.67$ m/s^2

13) When a hydrocarbon fuel is burned , almost all of the carbon in the fuel burns

completely to form CO_2 , which is the principle gas causing the greenhouse effect and thus global climate change. On average ,0.59 kg of CO_2 is produced for each kWh of electricity generated from a power plant that burns natural gas. A typical new household refrigerator uses about 700 kWh of electricity per year. Determine the amount of CO_2production that is due to the refrigerators in a city with 200000 households.

14) Storage is required for 35000 kg of propane , received as a gas at 10^0C and 1 atm. Two proposals have been made:

i) Store it as a gas at 10^0C and 1 atm.

ii) Store it as a liquid in equilibrium with its vapor at 10 ^{0}C and 6.294 atm. For this mode of storage , 90% of the tank volume is occupied by liquid.

Compare the two proposals ,discussing the pros and cons of each. Be quantitative wherever possible.

Data: $\omega = 0.152$, $T_C = 369.8$ K, $P_C = 42.48$ bar , $Z_C = 0.276$, $V_C = 200$ cm^3/mole.

15) A mass of 15 kg of air in a piston cylinder device is heated from 25^0C to 77^0C by passing current through resistance heater inside the cylinder. The pressure inside the cylinder is held constant at 300 kPa during the process. Determine the electrical energy supplied in kWH. $C_v = 0.718$ kJ/kg K

16) With neat sketch ,explain P - v diagram.

17) Handbook value for the latent heat of vaporization at 298.15 K for n-pentane is 366.3 J/g. Calculate ΔH_n by Watson equation and compare the result with the given experimental value.

(Data: $\omega = 0.252$,$T_c = 469.7$ K, $P_c = 33.70$ bar , $T_n = 309.2$ K, $\Delta H_n = 25.79$ kJ/mol)

18) One mole of an ideal gas, initially at 30 ^{0}C and 1 bar, undergoes the following mechanically reversible changes. It is compressed isothermally to a point such that when it is heated at constant volume to 120 ^{0}C its final pressure is 12 bar. Calculate Q, W, ΔU and ΔH for the process. Take Cp = (7/2) R and Cv = (5/2) R. Sketch the path of the process on P-V diagram.

19) The turbine in a hydroelectric plant are fed by water falling from a 50 m height. Assuming 91% efficiency for the conversion of potential to electrical energy , and 8% loss of resulting power in transmission , what is the mass flow rate of water required to power a 200 W light bulb?

20) A candle is burning in a well insulated room, Taking the room (the air plus the candle) as the system , determine

i) if there is any heat transfer during this burning process

ii) if there is any change in the internal energy of the system.

21) Give the mathematical expression for Gibb's phase rule for non-reacting system. How many degree of freedom has the following system. Calculate.

System : Saturated salt solution in equilibrium with its vapor and with some excess salt crystals present.

22) A 30 m^3 tank contains 14 m^3 of liquid butane in equilibrium with its vapor at 298.15 K. Estimate the mass of n butane vapor in the tank. The vapor pressure of n butane at the given temp. is 2.43 bar.

Data: Molar mass = 58, ω = 0.200 , T_c = 425.1 K, P_c = 37.96 bar, Z_c= 0.274 and V_c= 255 cm^3/mol

23) A student living in a 4m x 6m x 6m dormitory room turns on her 150 w fan before she leaves the room on a summer day, hoping that the room will be cooler when she comes back in the evening .Assuming all the doors & windows are tightly closed & disregarding any heat transfer through the walls & the windows , determine the temperature in the room when she comes back 10 hr later. Assume room to be at 100 kPa & 15 ^{0}c in the morning when she leaves.(Justify the increase or decrease briefly)

Avg. specific heat capacity of air = C_v air = 0.718 kJ /kg. K

24) One mole of air, initially at 150 ^{0}C and 8 bar, undergoes the following mechanically reversible changes. It expands isothermally to a pressure such that when it is cooled at constant volume to 50 ^{0}C its final pressure is 3 bar. Assuming air as an ideal gas for which C_p =(7/2) R and C_v = (5/2) R, calculate Q, W, ΔU and ΔH for the process. Show the process on P-V diagram.

25) For a steady flow through a heat exchanger at approximately atmospheric pressure, what is the final temperature when heat in the amount of 2500 kJ is added to 15 mol of 1 butene initially at 533.15 K? (Solve by iterative method)

Molar mass of 1-Butene = 56

26) A tank containing 20 kg of water at 20 ^{0}C is fitted with a stirrer that delivers work to water at the rate of 0.25 kW, how long does it rake for temp of water to raise to 30 ^{0}c if no heat is lost from water to its surrounding . for water cp = 4.18 kJ /kg ^{0}C

27) In a chemical process plant , water at 67^{0}C is pumped from a storage tank at the rate of 20000kg/hr. The motor for the pump expenses work at the rate of 1.5 hp. The water

passes through the heat exchanger and rejects the heat at a rate of 38000 kJ/min. and is delivered to the next storage tank at an elevation of 20 m above the first tank.
Determine the temperature of the water delivered to the second tank, given that
C_p = 4.2 kJ /kg.K.

28) One kmole of an ideal gas ,initially at 303.15 K and 1 bar ,undergoes the following mechanically reversible changes. It is compressed isothermally to a point such that when it is heated at constant volume to 393.15 K its final pressure is 12 bar. Calculate Q,W, ΔU and ΔH for the process. Take C_p = (7/2) R and C_v = (5/2) R.

Unit II

1) Which is the more effective way to increase the thermal efficiency of a Carnot Engine :
To increase T_h with T_c constant ,or to decrease T_c with T_h constant ? For a real engine , which would be the more practical way?

2) Staring with fundamental property relations and using Max well's equations , derive the following expression.

$$dS = C_p \frac{dT}{T} - \left(\frac{\partial V}{\partial T}\right)_p dP$$

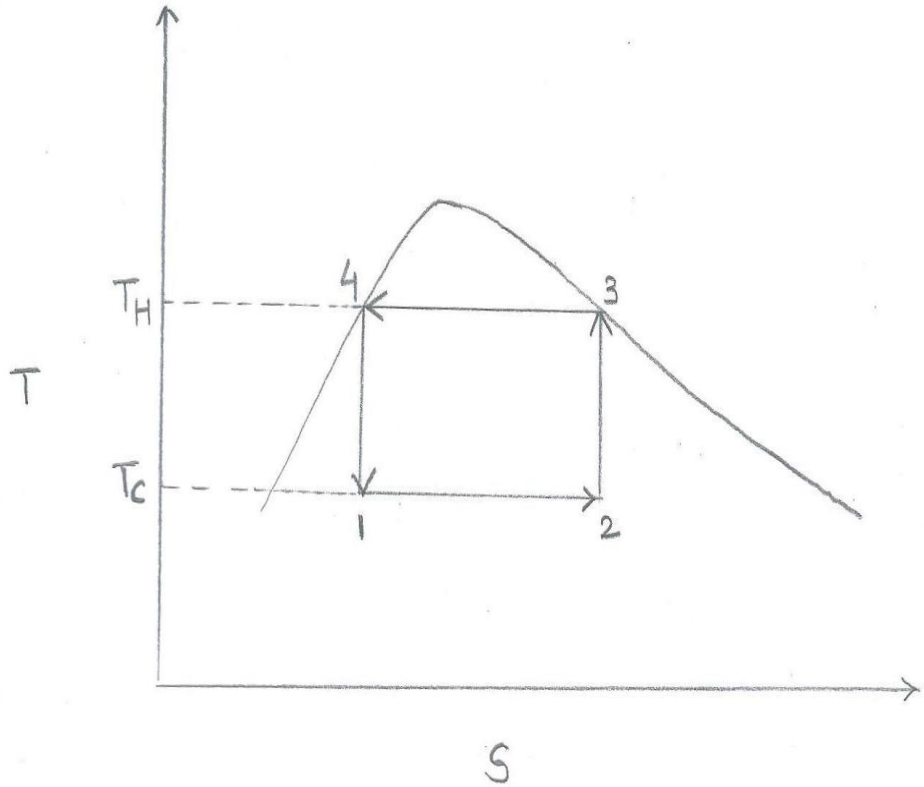
For ideal gas, what form these equations will take?

(3) What is Liquefaction. State its significance and applications. How it is accomplished . Explain with the help of *T-S* diagram.

(4) A Carnot refrigerator has tetrafluroethane a the working fluid. The cycle is as shown below. For T_C = - 10 ^{0}C and T_H = 40 ^{0}C Determine:

i) Pressure at states 1,2,3 and 4.
ii) Quality x at state 1 and 2.
i) Heat addition per kg of fluid
ii) Heat rejection per kg of fluid
iii) Mechanical power per kg of fluid for each of the four steps.

iv) Coefficient of performance ω for the cycle.



5) Large quantities of liquefied natural gas (LNG) are shipped by ocean tankers. At The unloading port provision is made for vaporization of the LNG so that it may be delivered to pipeline as gas. The LNG arrives in the tanker at atmospheric pressure and 113.7 K (- 159.45^{0}C), and represents a possible heat sink for use as a cold reservoir of a heat engine. For unloading of LNG as a vapor at a rate of 9000 $m^3\ s^{-1}$, as measured at 25 ^{0}C and 1.0133 bar , and assuming the availability of an adequate heat source at 30 ^{0}C, what is maximum possible power obtainable and what is the rate of heat transfer from the source? Assume that LNG at 25^{0}C and 1.0133 bar is an ideal gas with the molar mass of 17. Also assume that the LNG vaporizes only, absorbing only its latent heat of 512 kJ kg^{-1} at 113.7 K

6) Superheated steam at 500 kPa and 573.15 K expands,reversibly and adiabatically, to 50 kPa. What is its final enthalpy?

7) Staring with fundamental property relations and using Maxwell's equations , derive the following expression.

$$dH = C_p dT + \left[V - \left(\frac{\partial V}{\partial T}\right)_p\right] dP$$

For ideal gas, what form these equations will take?

8) A nuclear power plants generates 750 MW ; The reactor temperature is 315^0C (588.15K) and a river with water temperature of 20^0C (293.15K)is available.

i) What is the maximum possible thermal efficiency of the plant, and what is the minimum rate at which heat must be delivered to the river?

ii) If the actual thermal efficiency of the plant is 60 % of the maximum, at what rate must heat be discarded to the river ,and what is the temperature rise of the river if it has a flowrate of 165 m^3/s ?

9) Calculate value of latent heat of vaporization for chloroform at 273.15 K .

(Data: T_c = 536.4 K , P_C = 54.72 bar ,T_n = 334.3 K)

10) Air at 25^0C and 1 atm is cooled at a rate of 3000 m^3/h to – 8^0C b refrigeration. For the surrounding temperature of 25 ^{0}C , what is the minimum power requirement in kW?

Unit III

1) Vessel contains 1 kg of H_2O as liquid and vapor in equilibrium at 1000 kPa. If the vapor occupies 70 % of the volume of the vessel, determine the H and S for 1 kg of H_2O.

2) A turbine operates adiabatically with superheated steam entering at T_1 and $P_1$with a mass flow rate $\dot{m}$. The exhaust pressure is P_2 and the turbine efficiency η For the following set of operating conditions , determine the power output of the turbine and the enthalpy and entropy of the exhaust steam.

T_1= 473.15 K , P_1 =1400 kPa, $\dot{m}$= 50 kg s^{-1} , P_2 = 200 kPa, η = 0.7

3) From data in the steam tables:

i) Determine the value of G^l and G^v for saturated liquid and vapor at 1500 kPa. Should these be same?

ii) Determine the value for $\Delta H^{lv}/T$ and ΔS^{lv} at 1500 kPa. Should these be same?

4) An ammonia refrigeration system works between the temperature limits of - 6^0C and 26^0C. The vapor being dry saturated at the end of isentropic compression. There is no under cooling of liquid and expansion is by throttle valve. Calculate

i) The COP

ii) The power required to drive the compressor for a cooling effect of 60000 kJ/ h

iii) The amount of heat to be removed in the condenser in kJ/min.

Properties of Ammonia:

Temp ^{0}C	Enthalpy kJ/kg		Entropy kJ/kg K	
	Liquid	Vapor	Liquid	Vapor
26	303.6	1465.6	1.139	5.024
-6	153.5	1436.8	0.612	5.417

5) Write an informative account on : Choice of Refrigerant

6) Briefly explain response of throttling process to the fluid when it is ideal gas ,wet steam and saturated liquid ?

7) Steam at 2100 kPa and 533.15 K expands at constant enthalpy (as in throttling process)to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

8) Saturated steam at 100 kPa is compressed adiabatically to 300 kPa. If the compressor efficiency is 0.75 ,what is the work required and and what are the properties of the discharge stream?

9) Assuming Raoult's law to be valid prepare a *T-x,y* diagram for a pressure of 100 kPa for the Benzene (1)/ethyl benzene(2) system. Show subcooled liquid region, superheated vapor region , and saturation temperatures of pure specie on T-x,y diagram.

10) With neat sketch , explain the concept of retrograde condensation and its application to petroleum industry.

11) A liquid mixture of cyclohexane (1)/Phenol(2) for which x_1=0.6 is in equilibrium with its vapor at 417.15 K. Determine the equilibrium pressure P and vapor composition y_1 from the following information.:

$$\ln\gamma_1 = A\,(x_2)^2 \qquad\qquad \ln\gamma_2 = A\,(x_1)^2$$

At 417.15K, P_1^{sat} =75.20 and P_2^{sat} =31.66 kPa

The system forms an azeotrope at 417.15 K for which $x_1^{az} = y_1^{az} = 0.294$

12) Give the mathematical expression for Raoult's Law. State its the major assumptions. Give few examples of binary systems obeying Raoult's law with proper justification

13) What is the basic equation for the vapor liquid equilibrium calculations?

14) Draw P-x,y diagram at constant temperature for a minimum boiling azeotrope.

15) What kind of retrograde condensation can occur if a constant pressure line twice crosses the bubble point curve?

16) What is Henry law?

17) Assuming Raoult's law to be valid prepare a *t-x,y* diagram for a pressure of 90 kPa for 1-Chlorobutane(1)/ Chlorobenzene(2). Show on this diagram the superheated condition, sub cooled liquid condition ,bubble point and dew point position for the above binary mixture with 65% composition of specie (1).

18) A cooking gas cylinder is filled with LPG (a mixture of propane and butane) at 25^0 C and 4 bar. Assume that the mixture behaves like an ideal solution and the cylinder contains large amount of liquid phase and a small amount of vapor phase.

i) Determine the composition of the mixture with which the cylinder is filled ?

ii) When the gas is withdrawn from the cylinder for cooking for a few days, the

pressure reduces to 2.5 bar. Estimate the composition of the liquid in the cylinder when its pressure is 2.5 bar.

iii) Estimate the gas pressure when the cylinder contains 95 mole % butane.

Antoine constant for propane and butane are given as fallows :

	A	B	C
Propane	6.8299	813.2	248
Butane	6.8303	945.9	240

$$Log_{10} P = A - \frac{B}{t+C}$$

[where P is in Torr (1atm =760 Torr)and Temperature is in ^{0}C]

19) For the system of ethyl ethanoate (1)/n-heptane (2) at 343.15 K

$\ln \gamma_1 = 0.95 (x_2)^2$ $\ln \gamma_2 = 0.95 (x_1)^2$

P_1^{sat} =79.80 kPa and P_2^{sat} =40.50 kPa

Assuming the validity of modified Raoult's Law.

i) Make a BUBL P calculation for T= 343.15 K, x_1=0.25

ii) Make a DEW P calculation for T= 343.15 K, y_1=0.25

iii) Does azeotrope exist for this system. If yes, what is the azeotropic composition and pressure at T= 343.15 K

20) Ten kmol h^{-1} of hydrogen sulfide gas is burned with the stoichiometric amount of pure oxygen in a special unit. Reactants enter as gases at 25° C (298.15) and 1 atm. Products leaves as two streams in equilibrium at 70°C (343.15k)and 1 atm. a phase of pure liquid water, and saturated vapor stream containing H_2O and SO_2.

i) What is the composition (mole fraction) of the product vapor stream?

ii) What are the rates (kmol h^{-1}) of the two product streams?

21) What is the criteria for two phase equilibrium of binary system ?

22) Draw t-x,y and y-x diagrams for a binary solution which exhibits maximum boiling azeotrope.

23) What kind of retrograde condensation can occur if a constant temperature line twice crosses the dew point curve?

24) Assuming the validity of Raoult's law , do the following calculation for the benzene(1)/toluene(2) system.

i) Given x_1= 0.42 and P =130 kPa, find $y_1$and T. What is this point called?

ii) Given y_1=0.42 and T = 373.15 K, find $x_1$and P. What is this point called?

Antoine equation is as follows :

$$\ln P^{sat} /kPa = A - B/ (T /K + C)$$

Parameters for the Antoine Equation :

	A	B	C
Benzene	13.8594	2773.78	-53.08
Toluene	14.0098	3103.01	-53.36
H_2O	16.3872	3885.70	- 42.98

25) An industrial dehumidifier accepts 50 kmol h^{-1} of moist air with a dewpoint of 20 ^{0}C (293.15K) . Conditioned air leaving the dehumidifier has a dewpoint temperature of 10 ^{0}C (283.15K). At what rate (kg h-1) is liquid water removed in this steady flow process? Assume P is constant at 1 atm.

26) The following is the rule of thumb: For a binary system in VLE at low pressure, the equilibrium vapor phase mole fraction y_1 corresponding to an equimolar liquid mixture is approximately

$$y_1 = \frac{p_1^{sat}}{(p_1^{sat} + p_2^{sat})}$$

where P_i^{sat} is a pure specie vapor pressure. Clearly this equation is valid if Raoult's Law applies. Prove that it is also valid for VLE described by modified Raoult's Law, with

$$\ln \gamma_1 = A(x_2)^2 \qquad \ln \gamma_2 = A(x_1)^2$$

27) Write a critical account on Retrograde Condensation and its applicability.

Unit IV

1) Describe the graphical interpretation of equations for partial properties in binary solutions.

2) The enthalpy of binary liquid system of species 1 & 2 at T and P is given by

$$H = 400x_1 + 300x_1^2$$

Find the value of $\overline{H}_1^{\infty}$ and $\overline{H}_2^{\infty}$.

3) Derive an expression showing that chemical potential can be used as a criteria for phase equilibrium.

4) The partial molar volume of methanol in a methanol (1)-water (2)solution at x_1 = 0.3881 is 39.176x10^{-6} m^3/mol. The density of the mixture is 905.376 kg/m^3. Determine the partial molar volume of water in the solution.

5) Estimate the fugacity of cyclopentane at 110 ^{0}C and 275 bar. At 110^{0}C the vapor pressure of cyclopentane is 5.267 bar.

Molar mass of cyclopentane = 70, T_C= 511.8 ^{0}K , P_C =45.02 bar , Z_C = 0.273 , V_C =258 cm^3/mole and ω =0.196

6) For the following system ,determine Margules parameters and then apply the Margules equation to sufficient number of VLE calculations to allow the construction of P-x,y diagram at a given temperature.

System : 2- Butanone(1)/ Toluene (2) at 50 ^{0}C

γ_1^{∞} =1.47 γ_2^{∞} = 1.30 P_1^{sat} =36.09 kPa P_2^{sat} = 12.30 kPa

7) Is there any change in volume and enthalpy when two pure component are mixed to form an ideal solution?

8) What is an excess property?

9) The mathematical expression of $\frac{G^E}{x_1 x_2 RT}$ for liquid phase of binary system at T and P is expressed as

$$\frac{G^E}{x_1 x_2 RT} = A_{21}x_1 + A_{12}x_2$$

Derive the expression for $\ln \gamma_1$

10) At constant T and P ,The molar density of mixture is given by ρ=1+x_2 where x_2 is the molar fraction of component 2.Calculate the partial molar volume at infinite dilution of

component 1.

11) For H_2O at a temperature of 350 ^{0}C and for pressure up to 10000 kPa Calculate values of f_i and ϕ_i from data in the steam table and plot them vs P.

12) Under atmospheric condition, the acetone – chloroform azeotrope boils at 64.6^0 C and contains 33.5 mol percent acetone . The vapour pressure of acetone and chloroform at this temperature are 995 mm Hg and 885 mm Hg respectively. Calculate the composition of the vapor at this temperature in equilibrium with a liquid analyzing 25 mol percent acetone. Apply the Margules equation .

13) With reference to given H-x diagram for H_2SO_4/ H_2O system, solve the following:

i) What is the nature of this given system? Exothermic or endothermic? What about ΔH for such systems?

iI) It is proposed to cool a stream of 70 mass% sulfuric acid solution at 80 ^{0}C by diluting it with chilled water at 10 ^{0}C . Determine the amount of water that must be added to 2.5 kg of 70% acid before cooling below 40^{0}C actually occurs.

13) What is the Lewis Randall rule?

14) What is partial molar property ? How do you differentiate between molar volume and partial molar volume?

15) For H_2O at a temperature of 400 ^{0}C and for pressure up to 10000 kPa Calculate values of f_i and ϕ_i from data in the steam table and plot them vs P.

16) Under atmospheric condition, the acetone – chloroform azeotrope boils at 64.6^0 C and contains 33.5 mol percent acetone . The vapour pressure of acetone and chloroform at this temperature are 995 mm Hg and 885 mm Hg respectively. Calculate the composition of the vapor at this temperature in equilibrium with a liquid analyzing 11.1 mol percent acetone. Apply the van Laar equation .

17) Eleven thousand kg/hr. of an 70 mass% H_2SO_4 solution in water at 50 ^{0}C is continuously diluted with chilled water at 10 ^{0}C to yield a stream containing 45 mass% H_2SO_4 at 25 ^{0}C .

i) What is the mass flow rate of chilled water in kg/hr.?

ii) What is the rate of heat transfer in kJ/hr. for the mixing process? Is heat added or removed?

iii) If the mixing occurred adiabatically , what would be the temperature of the product stream?

Assume here the same inlet conditions and the same product compositions as for part (ii).

18) Calculate the partial molar volume of water in a 50 mole percent ethanol water solution in which the partial molar volume of ethanol is 52.37×10^{-6} m^3/mol. Given that the density of the mixture is 800.21 kg/m^3.

19) Estimate the fugacity of 1-Butene at its normal boiling point temperature and 150 bar.

T_{normal} = 266.9 K , ω = 0.191, T_c = 420 K, P_c = 40.43 bar, Z_c= 0.277 and V_c= 239.3 cm^3/mol

20) If a liquid solution of HCl in water , containing 1 mol of HCl and 4.5 mol of H_2O absorbs an additional 1 mol of HCl(g) at constant temperature of 25 ^{0}C, What is the heat effect? For heat of solution of HCl (g) refer given figure.

21) An insulated tank , open to the atmosphere , contain 680 kg of 40 mass% H_2SO_4 at 20^{0}C . It is heated to 80 ^{0}C by injection of live saturated steam at 1 atm , which fully condenses in the process.How much steam is required and what is the final concentration of H_2SO_4 in the tank?

22) For the following system of methanol(1)/methyl acetate (2),the following equations provides a reasonable correlation for the activity coefficient:

$$\ln \gamma_1 = A (x_2)^2 \qquad \ln \gamma_2 = A (x_1)^2$$

where $A = 2.771 - 0.00523\,T$

In addition, the following Antoine Equation provide vapor pressures :

$$\ln P_1^{sat}/\text{kPa} = 16.5915 - 3643.31/(T - 33.424)$$

$$\ln P_2^{sat}/\text{kPa} = 14.2533 - 2665.54/(T - 53.424)$$

where T is in Kelvin and vapor pressures are in kPa.

Assuming the validity of modified Raoult's Law,

Calculate P and y_1 , for T = 318.15 K and x_1 =0.25

23) An equimolar mixture of benzene and toluene is contained in a piston cylinder arrangement at temperature T. What is the maximum pressure below which this mixture will exist as vapor alone? At given temperature , vapor pressure of benzene and toluene are 1530 mm Hg and 640 mm Hg respectively. Assume Raoult's law is valid.

24) What is an azeotrope? How do you categorize an Azeotrpe? Discuss the minimum boiling azeotrope with the help of phase diagram for a particular system.

25) Ten kmol h^{-1} of hydrogen sulfide gas is burned with the stoichiometric amount of pure oxygen in a special unit. Reactants enter as gases at 25° C (298.15) and 1 atm. Products leaves as two streams in equilibrium at 70°C (343.15k)and 1 atm. a phase of pure liquid water, and saturated vapor stream containing H_2O and SO_2.

i) What is the composition (mole fraction) of the product vapor stream?

ii) What are the rates (kmol h^{-1}) of the two product streams?

26) A binary mixture of benzene (1)/and toluene (2) is flashed to 75 kPa and 90 ^{0}C (363.15K) Analysis of the effluent liquid and vapor streams from the separator yields x_1 =0.1604 and y_1 = 0.2919 . An operator remarks that the product streams are "off specification," and you are asked to diagnose the problem.

i) Verify that the exiting streams are not in binary equilibrium.

ii) Verify that an air leak into the separator could be the cause.

27) Derive an expression showing that chemical potential can be used as a criteria for phase equilibria.

28) A stream of nitrogen flowing at the rate of 2 kg/s and a stream of hydrogen flowing at the rate of 0.5 kg/s mix adiabatically in a steady flow process. If the gases are assumed ideal , What is the rate of entropy increase as a result of the process?

29) Nine thousand kg/hr of an 80 mass% H_2SO_4 solution in water at 50^{0}C is continuously diluted with chilled water at 5^{0}C to yield a stream containing 50 mass% H_2SO_4 at 60^{0}C .

i) What is the mass flow-rate of chilled water in kg/hr?

ii) What is the rate of heat transfer in kJ/hr for the mixing process? Is heat added or removed?

iii) If the mixing occurred adiabatically , what would be the temperature of the product stream? Assume here the same inlet conditions and the same product compositions as for part (ii)

Unit V

1) The equilibrium constant for the reaction A → B is doubled when the temperature is changed from 25 ^{0}C to 35 ^{0}C. Calculate the enthalpy change of the reaction.

2) The water gas shift reaction,

$$CO\ (g) + H_2O\ (g) \text{ ---------- } CO_2\ (g) + H_2\ (g)$$

is carried out under different sets of conditions described below. Calculate the fraction of steam reacted in each case. Assume the mixture behaves as an ideal gas.

i)The reactants consists of 1mol of H_2O vapor and 1 mol of CO. The temperature is 1100 K and the pressure is 1 bar.

ii)Same as i) except that pressure is 10 bar.

iii)The reactants are 2 mol of H_2O and 1 mol of CO other conditions are (assume ln K = 0 for above reaction)

3) For the ammonia synthesis reaction written :

$$\frac{1}{2}N_2(g)+\frac{3}{2}H_2(g)\rightarrow NH_3(g)$$

with 0.5 mole of N_2 and 1.5 mole of H_2 as the initial amounts of reactants and with the assumption that the equilibrium mixture is an ideal gas, show that:

$$\varepsilon_e = 1-(1+1.299K\frac{P}{P^0})^{-1/2}$$

4) With neat sketch , write an informative account on fuel cell.

Data : Antoine equation to be used is as follows :

$$\ln P^{sat}/kPa = A - \frac{B}{T/K + C}$$, Parameters for the Antoine Equation

Chemical Specie	A	B	C
Benzene	13.8594	2773.78	-53.08
Ethyl Benzene	14.0045	3279.47	-59.95

5) What is the criteria of equilibrium for a chemically reacting system?

6) What is the influence of temperature on equilibrium?

7) How does the addition of inert gases affect the degree of conversion of a chemical reaction?

8) If a mixture of 1 mol of CO(g), 1 mol of H_2O, and 2 mol of He(g) are fed into a reactor At 10 bar and 1000 K, the following reaction occurs to produce carbon dioxide and Hydrogen gas :

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

The equilibrium constant for the reaction is 1.5. Calculate the degree of conversion and equilibrium composition of the reaction mixture behaves like an ideal gas.

9) Write a short note on : Fuel Cell

10) What is the effect of pressure on equilibrium conversion of a gas phase chemical reaction?

11) Methanol is produced by the following reaction:

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

The standard heat of formation of CO(g) and CH3OH(g) at 298 K are -110,500 J/mol and 200,700 J/mol respectively. The standard free energies of formation are -137,200 J/mol and -162,200 J/mol respectively.

(i) Estimate the standard free energy and determine whether the reaction is feasible at 298 K.

(ii) Determine the equilibrium constant at 400K, assuming that the heat of reaction is constant.

12) Develop the expression for the mol fraction of reacting species as a functions of the reaction coordinate for a system initially charged with 4 mol ethylene, 3 mol oxygen and the following reaction occurs between the species :

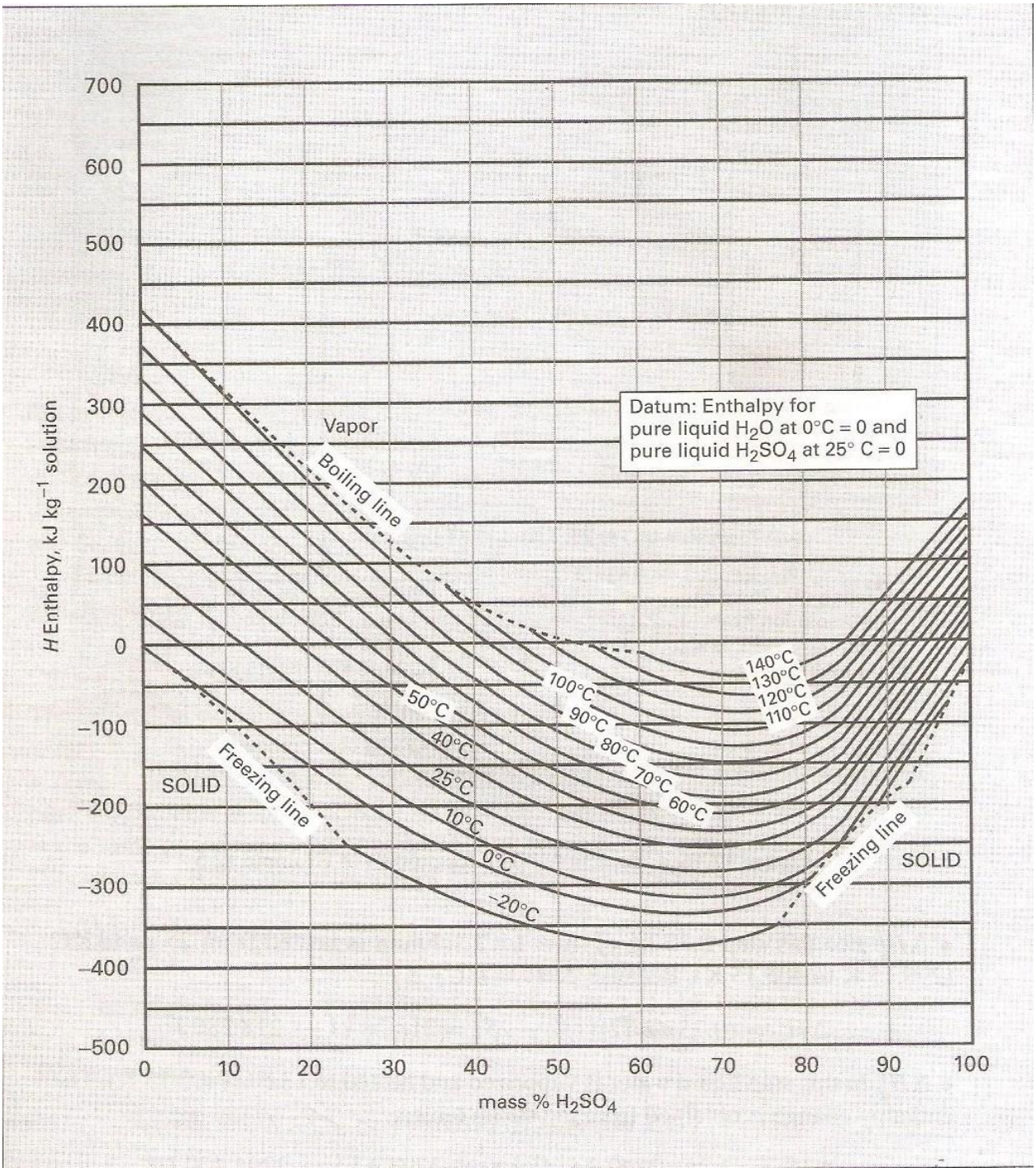
$$C_2H_4(g) + O_2(g) \rightarrow 2[(CH_2)O)](g)$$
$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$

13) A system initially containing 2 mol C_2H_4 and 3 mol O_2 undergoes the reaction :

$$C_2H_4\ (g) + ½\ O_2 \text{ ---------- } (\ (CH_2)_2)\ O\ (g)$$
$$C_2H_4\ (g) + 3\ O_2\ (g) \text{ ---------- } 2\ CO_2\ (g) + 2\ H_2O\ (g)$$

Develop expressions for the mole fractions of the reacting species as the function of the reaction coordinates for the two reactions.

14) Write a short note on Gibb's phase rule for reacting system.


700
600
500
400
300
200
100
0
−100
−200
−300
−400
−500
H Enthalpy, kJ kg−1 solution
0
10
20
30
40
50
60
70
80
90
100
mass % H2SO4
Datum: Enthalpy for pure liquid H2O at 0°C = 0 and pure liquid H2SO4 at 25° C = 0
Vapor
Boiling line
Freezing line
SOLID
Freezing line
SOLID
140°C
130°C
120°C
110°C
100°C
90°C
80°C
70°C
60°C
50°C
40°C
25°C
10°C
0°C
−20°C