KATHMANDU UNIVERSITY
End Semester Examination [C]
January, 2019

Marks Scored:

Level : B.E.
Year : II
Course : CHEG 211
Semester : II
Exam Roll No. :
Time: 30 mins.
F.M. : 10
Registration No.:
Date JAN 0 1 2019

SECTION "A"

[20 Q.×0.5=10 marks]

Tick the most appropriate answer.

1. According to the first law of thermodynamics, dU equals (dQ + dW) for a closed system. U stands for
   a. heat b. internal energy c. work d. entrophy

2. When one mole of an ideal gas is expanded irreversibly from P_1 to P_2 at a constant temperature (T), the associated amount of work (W) is
   a. $W = -P_2(\frac{RT}{P_2} - \frac{RT}{P_1})$ b. $W = -RT\ln(\frac{P_1}{P_2})$
   c. $W = -P_1(\frac{RT}{P_2} - \frac{RT}{P_1})$. d. $W = -RT\ln(\frac{P_2}{P_1})$.

3. Compared with the molar heat capacity of liquid water at constant pressure, the molar heat capacity of the water at constant volume is
   a. larger. b. smaller. c. nearly the same. d. indeterminate.

4. The molar heat capacity of ideal nitrogen gas at constant pressure is
   a. $\left(\frac{5}{2}\right)R$ where R is the gas constant. b. $3R$ where R is the gas constant.
   c. $\left(\frac{7}{2}\right)R$ where R is the gas constant. d. $4R$ where R is the gas constant.

5. If 100 J of heat is added reversibly to 1 mole of a liquid at 300 K and 1 atm whose molar heat capacity is $100\frac{J}{mol\cdot K}$, the entropy change of the liquid is
   a. $\frac{100}{300}\, J\, K^{-1}$. b. - $\frac{100}{300}\, J\, K^{-1}$.
   c. $100\ln\left(\frac{301}{300}\right) J\, K^{-1}$. d. indeterminable.

6. The entropy of an ideal gas
   a. decreases with isothermal compression.
   b. decreases with isothermal expansion.
   c. decreases with reversible adiabatic expansion.
   d. increases with reversible adiabatic compression.

7. The entropy change of the surroundings of a Carnot cycle engine is
   a. negative. b. positive. c. zero. d. indeterminable.

8. The Gibbs energy change of an ideal gas (ΔG) at constant temperature (T) is related to the entropy change (ΔS) as follows:
   a. $\Delta G = T\Delta S$. b. $\Delta G = -T\Delta S$. c. $\Delta G > T\Delta S$. d. $\Delta G < T\Delta S$.

9. The residual enthalpy of an ideal gas (H^R) is
   a. negative. b. zero. c. positive. d. indeterminate.

10. An equi-molar mixture of water and ethanol is placed in a flask and is heated under atmospheric pressure.
a. The degree of freedom for the binary system is one at vapor-liquid equilibrium.
b. The mixture boils at the temperature when the vapor pressure of the mixture equals atmospheric pressure.
c. In the vapor phase the mole fraction of water is higher than that of ethanol.
d. The dew point temperature equals the bubble point temperature.

11. Although a liquid mixture is non-ideal, the Raoult's law can be applied
a. for equi-molar solution.
b. for all the components when system temperature is high enough.
c. for a component, the mole fraction of which is close to 0.
d. for a component, the mole fraction of which is close to 1.

12. For a binary mixture, the number of operating variables that can be varied independently at vapor-liquid equilibrium is
a. 1 b. 2 c. 3 d. 4

13. The activity coefficient (γ_i) of a species in a liquid mixture can be represented by $\gamma_i = \frac{f_i'}{x_i f_i}$ where f_i' is the fugacity of the species in the mixture and x_i is the mole fraction of the species in the liquid phase. While, f_i in the denominator represents
a. the fugacity of pure species i at the given operating condition
b. the partial pressure of pure species i at the given operating condition.
c. the escaping tendency of species i in the mixture.
d. the vapor pressure of pure species i.

14. The UNIFAC model is used to calculate the ------------- of a component in a solution.
a. activity coefficient b. vapor pressure
c. excess volume d. excess enthalpy

15. According to the Gibbs/Duhem equation, an increase in activity coefficient of a component in a binary liquid mixture
a. would decrease the activity coefficient of the other component.
b. would increase the activity coefficient of the other component.
c. would decrease or increase the activity coefficient of the other component depending on operating condition.
d. would have little influence on the activity coefficient of the other component if the system pressure is low enough.

16. One mole of nitrogen and one mole of oxygen are mixed at 25°C and 1 atm.
a. The Gibbs energy of nitrogen increases.
b. The partial molar enthalpy of oxygen decreases.
c. The fugacity of nitrogen decreases.
d. The entropy of oxygen decreases.

17. The dissolution of NaOH in water is an exothermic process. The adiabatic temperature after the dissolution
a. would increase.
b. would decrease.
c. would be the same as the temperature before dissolution.
d. cannot be predicted unless further information is provided.

18. A mixture of benzene and toluene is at vapor-liquid equilibrium.
    a. The partial pressure of benzene is the product of the vapor pressure of benzene and the mole fraction of benzene in the vapor phase.
    b. The partial pressure of benzene is the product of the vapor pressure of benzene and the mole fraction of benzene in the liquid phase.
    c. The escaping tendency of benzene in the liquid phase is the same as the escaping tendency of benzene in the vapor phase.
    d. The chemical potential of benzene is equal to the fugacity of benzene.

19. For water gas shift reaction represented by $CO + H_2O = CO_2 + H_2$, the chemical potential of CO is
    a. the molar Gibbs energy of pure CO.
    b. the molar entropy of CO in the reaction mixture.
    c. the activity of CO in the reaction mixture.
    d. the partial molar Gibbs energy of CO in the reaction mixture.

20. Hydrogen is primarily produced by steam reforming of methane gas, which is represented by $CH_4 + H_2O = CO + 3H_2$. The activity of CH_4 in the reaction mixture is
    a. the ratio of the partial molar Gibbs energy of CH_4 in the mixture to the molar Gibbs energy of pure CH_4
    b. is the ratio of the partial pressure of CH_4 in the mixture to the standard pressure.
    c. the ratio of the fugacity of CH_4 in the mixture to the fugacity of pure CH_4 at the standard pressure and 25°C.
    d. the ratio of the fugacity of CH_4 in the mixture to the fugacity of pure CH_4 at the standard pressure and reaction temperature.

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SECTION "B"

Attempt *ALL* questions.

1. One mole of nitrogen at 5 bar and 25°C is expanded to 1 bar in a closed system. Assume that nitrogen is an ideal gas ($C_v = 20.78$ J mol^{-1} K^{-1} and $C_p = 29.10$ J mol^{-1} K^{-1}). Calculate the [6]
   1.1 amount of work for isothermal reversible expansion.
   1.2 amount of work for isothermal irreversible expansion.
   1.3 amount of work for adiabatic reversible expansion.

2. A stream of air at 150°C and 10 bar was expanded to 50°C and 1 bar at a rate of 1 mol/s. The cold reservoir temperature is 30°C and $C_P/R = 7/2$ is assumed for air. The entropy change associated with the expansion can be represented by $\Delta S = \int_{T_1}^{T_2} \frac{C_P dT}{T} - R\ln\frac{P_2}{P_1}$.[4]
   2.1 Calculate the rate of enthalpy change of the air with the expansion.
   2.2 Calculate the maximum amount of work obtainable using the thermodynamics law, $\Delta S_{fs} - \sum_j \frac{Q_j}{T_{\sigma,j}} = S_G \geq 0$.

3. VLE data for methyl tert-butyl ether (1)/dichloromethane (2) at 35°C are as follows: [4]

P, kPa	x_1	y_1
85.265	0.0000	0.0000
80.481	0.0924	0.0416
72.422	0.2482	0.1314
65.096	0.3880	0.2457
56.833	0.5749	0.4564
51.620	0.7676	0.7176
50.455	0.8476	0.8238
49.720	0.9529	0.9502
49.624	1.0000	1.0000

   3.1 At $x_1 = 0.7676$ and 35°C, determine the bubble point pressure, the mole fraction of tert-butyl ether in the first bubble, and the equilibrium ratio, K_1.
   3.2 Compare measured bubble point pressure at 35°C and $x_1 = 0.2482$ with the bubble point pressure predicted by the Raoult's law.

4. Initially 2 moles C_2H_4 and 5 moles O_2 undergo the following reactions:
   $C_2H_4(g) + 1/2O_2(g) \rightarrow C_2H_4O(g)$
   $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

   Determine the molar composition at the extents of reaction of 0.3 moles for the first reaction and 0.5 moles for the second reaction. [4]

5. Thermodynamic data for steam reforming of CH_4 ($CH_4 + H_2O = 3H_2 + CO$) in the gas phase are given as follows:

species	$\Delta_f H^0$ at 25°C, J/mol	$\Delta_f G^0$ at 25°C, J/mol	$\frac{C_P}{R} = A + BT + CT^2 + \frac{D}{T^2}$			
			A	B x 10^3	C x 10^6	D x 10^{-5}
CH_4	-74,520	-50,460	1.702	9.081	-2.164	0
H_2O	-241,818	-228,572	3.470	1.450	0	0.121
H_2	0	0	3.249	0.422	0	0.083
CO	-110,525	-137,169	3.376	0.557	0	-0.031

$\Delta_f H^0$ and $\Delta_f G^0$ represent standard heat of formation and standard Gibbs energy of formation at 1 bar, respectively, R is 8.314 J mol^{-1} K^{-1}, C_p is molar heat capacity (J mol^{-1} K^{-1}) , and T is reaction temperature in Kelvin. [6]

5.1 Determine the chemical equilibrium constant at 25°C.
5.2 Determine the chemical equilibrium constant at 1000 K.

6. An electrically heated tank containing 200 kg of water is maintained at 50°C with a cold water at 20°C entering the tank at the rate of 0.1 kg/s and the hot water leaving the tank at the same rate. Assume that the specific heat of water is constant at 4.2 kJ kg^{-1} K^{-1}. [4]
6.1 Calculate the rate of energy supply to the tank at the steady state.
6.2 Suddenly the electric power input to the tank was cut off. Calculate the time it would take for the temperature of water in the tank to drop to 30°C.

7. The entropy change for ideal gas can be represented by $dS = \frac{C_p dT}{T} - R\frac{dP}{P}$. 1 mole of oxygen at 1 bar was mixed with 2 moles of nitrogen at 1 bar isothermally at 25°C. [4]
7.1 After mixing, determine the total pressure and the partial pressure of nitrogen.
7.2 Calculate total entropy change by the mixing.

8. General equation to calculate a partial property in binary solutions can be represented by
$M_1' = M + x_2\frac{dM}{dx_1}$, $M_2' = M - x_1\frac{dM}{dx_1}$ where M is the property of a mixture. The molar enthalpy of a binary liquid system at fixed temperature and pressure is given by
H (J/mol) = $400x_1 + 600x_2 + x_1x_2(40x_1+20x_2)$ where x_1 is the mole fraction of species 1 and x_2 is the mole fraction of species 2. [4]
8.1 Derive the equation to determine the partial molar enthalpy of species 1.
8.2 Show that an increase of partial molar enthalpy of species 1 results in a decrease of partial molar enthalpy of species 2.

9. Using the steam Table 1 below, [4]
9.1 Calculate the entropy of saturated steam at 100.8 °C
9.2 Calculate the enthalpy of steam at 100°C with a quality of 0.8.

Table 1. Properties of saturated steam

temp.,°C	pressure, kPa	enthalpy, kJ kg^{-1}		entropy, kJ kg^{-1} K^{-1}	
		saturated water	saturated vapor	saturated water	saturated vapor
25	3.166	104.8	2547.3	0.3670	8.5592
100	101.33	419.1	2676.0	1.3069	7.3554
102	108.78	427.5	2679.1	1.3294	7.3315