

KATHMANDU UNIVERSITY
End Semester Examination [C]
June/July 2024

Marks Scored:

Level : B.E.

Year : II

Exam Roll No. :

Time: 30 mins.

Registration No.:

Course : CHEG 211

Semester : II

F. M. : 10

Date : 01 JUL 2024

SECTION "A"

[20Q. × 0.5 = 10 marks]

Choose and encircle the most appropriate answer.

- 5 kg of water and 5 kg of alcohol are put in a container in vapor liquid equilibrium. How many extensive variables does this system have?
a. 0 b. 1 c. 2 d. 3
- The activity coefficient of a component in a liquid mixture
a. Approaches to 1 as its mole fraction approaches to 0
b. Is the ratio of actual partial pressure to the partial pressure predicted by Raoult's law
c. Varies significantly with the system pressure
d. Is the ratio of actual fugacity to the fugacity predicted by assuming ideal solution
- If the equilibrium constant for the reaction $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ is $1/K^2$, the equilibrium constant for the reaction $\text{H}_2 + 1/2\text{O}_2 \rightarrow \text{H}_2\text{O}$ at the same temperature is
a. K b. $1/2K$ c. $2K$ d. $1/K^2$
- If the Emf of the cell is 1.184 volts, the Gibbs free energy of a reaction for a hydrogen fuel cell is
a. $-228,512 \text{ J.mol}^{-1}$ b. $228,512 \text{ J.mol}^{-1}$ c. $268,572 \text{ J.mol}^{-1}$ d. $-268,572 \text{ J.mol}^{-1}$
- Pick out the correct statement.
a. The absolute value of standard entropy for elementary substances is 0
b. Maximum work is done under reversible conditions
c. Melting of ice involves increase in enthalpy and decrease in randomness
d. Internal energy of an ideal gas depends only on its pressure
- Two substances are in equilibrium in a reversible chemical reaction. If the concentration of each substance is doubled, then the value of the equilibrium constant will be
a. Doubled b. Same
c. Halved d. One third of its original value
- According to the Gibbs/Duhem equation for a binary mixture
a. The activity coefficients of the two components are the same
b. The activity coefficient of a component increases with its mole fraction
c. An increase in the activity coefficient of a component results in a decrease in activity coefficient of the other component.
d. The activity coefficient of a component is maximum at a mole fraction of 1.
- The fugacity coefficient of a gas at constant pressure _____ with the decrease of temperature.
a. Increases
b. Decreases
c. Remains the same
d. Fugacity coefficient doesn't depend on temperature

9. If temperature of a two phase system in equilibrium is changed, the _____ must also change for the two phases to continue to coexist in equilibrium.
- Volume
 - Enthalpy
 - Chemical potential
 - Pressure
10. The partial pressure of a component in the vapor phase for vapor liquid equilibrium of ideal mixtures at low pressures can be calculated by
- Ideal gas law
 - Clapeyron equation
 - Raoult's law
 - Antoine equation
11. Calculate the internal energy change when 290 kg of air is cooled from 70 to 40 C in a constant volume process. The constant volume heat capacity of air is 2×10^4 J/kgmol.C.
- 6 MJ
 - 6 MJ
 - 50 MJ
 - 60 MJ
12. For the stoichiometric reaction $\text{CO (g)} + 2\text{H}_2 \text{(g)} \rightarrow \text{CH}_3\text{OH (g)}$, what is the value of equilibrium constant K at 298 K if the Gibbs free energy for CO and CH₃OH are -137,169 and -161,960 J/mol respectively.
- 10000
 - 15250
 - 18347
 - 22051
13. For the problem in question 12, what is the reaction coordinate (ϵ) ?
- 0.83
 - 0.89
 - 0.94
 - 0.98
14. For the problem in question 12, if the equilibrium methanol mole fraction is equal to 0.5, what is the equilibrium constant?
- 15
 - 22
 - 27
 - 32
15. For ideal gas state, the enthalpy change of mixing is
- 0
 - 1
 - 2
 - 3
16. One mole of an ideal gas is compressed isothermally but irreversibly at 100 C from 2.5 bar to 6.5 bar. What is the entropy change of the gas?
- 8 J/K
 - 9 J/K
 - 10 J/K
 - 11 J/K
17. For the reaction, $\text{H}_2 + 0.5\text{O}_2 \rightarrow \text{H}_2\text{O}$, what is the mole fraction of O₂ molecule if stoichiometric amounts of reactants are initially present?
- $0.5 - 0.5\epsilon / 1.5 - 0.5\epsilon$
 - $\epsilon / 5 + 0.5\epsilon$
 - $0.5\epsilon / 5 + 0.5\epsilon$
 - $1 + \epsilon / 5 + 0.5\epsilon$
18. Air is compressed from an initial state of 3 bar and 600 K to a final state of 8 bar and 600 K by three different mechanically reversible processes in a closed system. What is the ΔU for the process?
- 1267 J
 - 1621 J
 - 2421 J
 - 0 J
19. How many phase rule variables must be specified to fix the thermodynamic state for liquid water in equilibrium with its vapor?
- 0
 - 1
 - 2
 - 3
20. 1 mol of 1-butene liquid with normal boiling point of 267 K is vaporized. Estimate the latent heat for the phase change based on Trouton's rule.
- 20,157 J
 - 22,198 J
 - 25,143 J
 - 32,587 J

KATHMANDU UNIVERSITY
End Semester Examination [C]
June/July 2024

Level : B.E.
Year : II
Time : 2 hrs. 30mins.

01 JUL 2024

Course : CHEG 211
Semester : II
F. M. : 40

SECTION "B"

Attempt ALL questions.

1. A steady-flow adiabatic turbine accepts gas at conditions $T_1 = 500$ K, $P_1 = 6$ bar, and discharges at conditions $T_2 = 371$ K, $P_2 = 1.2$ bar. Take $T_{surr} = 300$ K and $C_p = 3.5R$. Assuming ideal gases, determine (per mole of gas)
 - a. Actual work [2]
 - b. Ideal work [2]
 - c. Lost work [2]
 - d. Entropy generation rate [2]

2. Estimate H^R and S^R for a 40-60% mixture of oxygen and nitrogen at 100 K and 50 bar using the Lee/Kesler correlation. [6]

3. Calculate the fraction and the composition of liquid that will remain at equilibrium when a mixture of 68.6% hexane and the balance toluene is flashed at 80 °C and 1 atm. The vapor pressures of hexane and toluene are 1020 and 290 mm Hg respectively. [6]

4. For the system ethylene (1) / propylene (2) as a gas,

For ethylene,	For propylene,
$P_{c,1} = 50.4$ bar	$P_{c,2} = 46.65$ bar
$T_{c,1} = 282.3$ K	$T_{c,2} = 365.6$ K
$V_{c,1} = 131$ cm ³ /mol	$V_{c,2} = 188.4$ cm ³ /mol
$Z_{c,1} = 0.281$	$Z_{c,2} = 0.289$
$\omega_1 = 0.087$	$\omega_2 = 0.140$

 - a. Estimate $\hat{f}_1, \hat{f}_2, \hat{\phi}_1, \hat{\phi}_2$ at $T = 150$ °C and $P = 30$ bar and $y_1 = 0.35$. [8]
 - b. Assuming that the mixture is an ideal solution. [5]

5. The water gas shift reaction to produce hydrogen $H_2O + CO \leftrightarrow CO_2 + H_2$ is to be carried out at 1000 K and 10 atm. The following data is provided for 1000 K and 10 atm.
 $G_{CO}^o = -47,860$ cal/mol $G_{CO_2}^o = -94,630$ cal/mol $G_{H_2O}^o = -46,040$ cal/mol
 - a. Calculate the equilibrium constant. [2]
 - b. Calculate the equilibrium conversion. [3]
 - c. Calculate the equilibrium concentration of each species. [2]

Useful equations and tables (to be provided with the question):

$$R = 8.314 \frac{J}{\text{mol} \cdot K} = 82.058 \text{ cm}^3 \cdot \frac{\text{atm}}{K \cdot \text{mole}} = 8.2 \times 10^{-5} \text{ m}^3 \cdot \frac{\text{atm}}{K \cdot \text{mole}}$$

$$\Delta S = \int_{T_1}^{T_2} \frac{C_p}{T} dT - nR \ln \frac{P_2}{P_1}$$

$$\prod_i (y_i \phi_i)^{v_i} = \left(\frac{P}{P_0}\right)^{-v} K$$

$$y_i \phi_i P = x_i \gamma_i P_i^{\text{sat}}$$

$$\ln \gamma_i = \left[\frac{\partial \left(\frac{nG^E}{RT} \right)}{\partial n_i} \right]_{P, T, n_j}$$

$$Z = 1 + \frac{BP}{RT}$$

$$B = \sum_i \sum_j y_i y_j B_{ij}$$

$$\frac{H^R}{RT} = \frac{P}{R} \left(\frac{B}{T} - \frac{dB}{dT} \right)$$

$$\frac{S^R}{R} = - \frac{P}{R} \frac{dB}{dT}$$

$$\frac{H^R}{RT_c} = \frac{(H^R)^0}{RT_c} + \omega \frac{(H^R)^1}{RT_c}$$

$$\frac{S^R}{R} = \frac{(S^R)^0}{R} + \omega \frac{(S^R)^1}{R}$$

$$V_{cij} = \left(\frac{V_{ci}^{1/3} + V_{cj}^{1/3}}{2} \right)^3$$

$$\omega_{cij} = \frac{\omega_{ci} + \omega_{cj}}{2}$$

$$Z_{cij} = \frac{Z_{ci} + Z_{cj}}{2}$$

$$T_{cij} = (T_{ci} T_{cj})^{1/2} (1 - k_{ij})$$

$$P_{cij} = \frac{Z_{cij} RT_{cij}}{V_{cij}}$$

$$T_{rj} = \frac{T}{T_{cij}}$$

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$\hat{B}_{ij} = B^0 + \omega_{ij} B^1 \quad B_{ij} = \frac{\hat{B}_{ij} RT_{cij}}{P_{cij}}$$

$$\delta_{12} \equiv 2B_{12} - B_{11} - B_{22}$$

$$\ln \phi = \frac{P_r}{T_r} (B^0 + \omega B^1)$$

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$\ln \hat{\phi}_1 = \frac{P}{RT} (B_{11} + y_2^2 \delta_{12})$$

$$\ln \hat{\phi}_2 = \frac{P}{RT} (B_{22} + y_1^2 \delta_{12})$$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H^0}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \quad \sum_i \frac{z_i K_i}{1 + V(K_i - 1)} = 1$$

$$\Delta G^0 = \Delta H^0 - T\Delta S^0$$

$$\Delta H^0 = \Delta H_{298}^0 + \int_{298}^T \sum v_i C_{p,i}^0 dT \quad \Delta S^0 = \Delta S_{298}^0 + \int_{298}^T \sum \frac{v_i C_{p,i}^0}{T} dT$$

	Molar mass	ω	T_c/K	P_c/bar	Z_c	$V_c/\text{cm}^3\cdot\text{mol}^{-1}$	T_R/K
Ethylene glycol	62.068	0.487	719.7	77.00	0.246	191.0	470.5
Acetic acid	60.053	0.467	592.0	57.86	0.211	179.7	391.1
Hydrogen	2.016	-0.216	33.19	13.13	0.305	64.1	20.4
Oxygen	31.999	0.022	154.6	50.43	0.288	73.4	90.2
Nitrogen	28.014	0.038	126.2	34.00	0.289	89.2	77.3
Air [†]	28.851	0.035	132.2	37.45	0.289	84.8	77.3

Table D.7: Values of $(H^R)^0/RT_c$

$P_r =$	1.0000	1.2000	1.5000	2.0000	3.0000	5.0000	7.0000	10.000
T_r								
0.30	-5.987	-5.975	-5.957	-5.927	-5.868	-5.748	-5.628	-5.446
0.35	-5.845	-5.833	-5.814	-5.783	-5.721	-5.595	-5.469	-5.278
0.40	-5.700	-5.687	-5.668	-5.636	-5.572	-5.442	-5.311	-5.113
0.45	-5.551	-5.538	-5.519	-5.486	-5.421	-5.288	-5.154	-4.950
0.50	-5.401	-5.388	-5.369	-5.336	-5.279	-5.135	-4.999	-4.791
0.55	-5.252	-5.239	-5.220	-5.187	-5.121	-4.986	-4.849	-4.638
0.60	-5.104	-5.091	-5.073	-5.041	-4.976	-4.842	-4.794	-4.492
0.65	-4.956	-4.949	-4.927	-4.896	-4.833	-4.702	-4.565	-4.353
0.70	-4.808	-4.797	-4.781	-4.752	-4.693	-4.566	-4.432	-4.221
0.75	-4.655	-4.646	-4.632	-4.607	-4.554	-4.434	-4.393	-4.095
0.80	-4.494	-4.488	-4.478	-4.459	-4.413	-4.303	-4.178	-3.974
0.85	-4.316	-4.316	-4.312	-4.302	-4.269	-4.173	-4.056	-3.857

Table D.8: Values of $(H^R)^1/RT_c$

$P_r =$	1.0000	1.2000	1.5000	2.0000	3.0000	5.0000	7.0000	10.000
T_r								
0.30	-11.062	-11.055	-11.044	-11.027	-10.992	-10.935	-10.872	-10.781
0.35	-10.640	-10.637	-10.632	-10.624	-10.609	-10.581	-10.554	-10.529
0.40	-10.121	-10.121	-10.121	-10.122	-10.123	-10.128	-10.135	-10.150
0.45	-9.525	-9.527	-9.531	-9.537	-9.549	-9.576	-9.611	-9.663
0.50	-8.888	-8.892	-8.899	-8.909	-8.932	-8.978	-9.030	-9.111
0.55	-8.238	-8.243	-8.252	-8.267	-8.298	-8.360	-8.425	-8.531
0.60	-7.596	-7.603	-7.614	-7.632	-7.669	-7.745	-7.824	-7.950
0.65	-6.980	-6.987	-6.997	-7.017	-7.059	-7.147	-7.239	-7.381
0.70	-6.388	-6.395	-6.407	-6.429	-6.475	-6.574	-6.677	-6.837
0.75	-5.824	-5.832	-5.845	-5.868	-5.918	-6.027	-6.142	-6.318
0.80	-5.285	-5.293	-5.306	-5.330	-5.385	-5.506	-5.632	-5.824
0.85	-4.763	-4.771	-4.784	-4.810	-4.872	-5.000	-5.149	-5.358
0.90	-4.249	-4.255	-4.268	-4.298	-4.371	-4.530	-4.688	-4.916
0.93	-3.934	-3.937	-3.951	-3.987	-4.073	-4.251	-4.422	-4.662
0.95	-3.712	-3.713	-3.730	-3.773	-3.873	-4.068	-4.248	-4.497

Table D.11: Values of $(S^R)^0/R$

$P_r =$	1.0000	1.2000	1.5000	2.0000	3.0000	5.0000	7.0000	10.000
T_r								
0.30	-7.099	-6.935	-6.740	-6.497	-6.180	-5.847	-5.683	-5.578
0.35	-6.663	-6.497	-6.299	-6.052	-5.728	-5.376	-5.194	-5.060
0.40	-6.275	-6.109	-5.909	-5.660	-5.330	-4.967	-4.772	-4.619
0.45	-5.924	-5.757	-5.557	-5.306	-4.974	-4.603	-4.401	-4.234
0.50	-5.608	-5.441	-5.240	-4.989	-4.656	-4.282	-4.074	-3.899
0.55	-5.324	-5.157	-4.956	-4.706	-4.373	-3.998	-3.788	-3.607
0.60	-5.066	-4.900	-4.700	-4.451	-4.120	-3.747	-3.537	-3.353
0.65	-4.830	-4.665	-4.467	-4.220	-3.892	-3.523	-3.315	-3.131
0.70	-4.610	-4.446	-4.250	-4.007	-3.684	-3.322	-3.117	-2.935
0.75	-4.399	-4.238	-4.045	-3.807	-3.491	-3.138	-2.939	-2.761
0.80	-4.191	-4.034	-3.846	-3.615	-3.310	-2.970	-2.777	-2.605
0.85	-3.976	-3.825	-3.646	-3.425	-3.135	-2.812	-2.629	-2.463
0.90	-3.738	-3.599	-3.434	-3.231	-2.964	-2.663	-2.491	-2.334
0.93	-3.569	-3.444	-3.295	-3.108	-2.860	-2.577	-2.412	-2.262
0.95	-3.433	-3.326	-3.193	-3.023	-2.790	-2.520	-2.362	-2.215

Table D.12: Values of $(S^R)^1/R$

$P_r =$	1.0000	1.2000	1.5000	2.0000	3.0000	5.0000	7.0000	10.000
T_r								
0.30	-16.586	-16.547	-16.488	-16.390	-16.195	-15.837	-15.468	-14.925
0.35	-15.278	-15.251	-15.211	-15.144	-15.011	-14.751	-14.496	-14.153
0.40	-13.896	-13.877	-13.849	-13.803	-13.714	-13.541	-13.376	-13.144
0.45	-12.496	-12.482	-12.462	-12.430	-12.367	-12.248	-12.145	-11.999
0.50	-11.153	-11.143	-11.129	-11.107	-11.063	-10.985	-10.920	-10.836
0.55	-9.914	-9.907	-9.897	-9.882	-9.853	-9.806	-9.769	-9.732
0.60	-8.799	-8.794	-8.787	-8.777	-8.760	-8.736	-8.723	-8.720
0.65	-7.810	-7.807	-7.801	-7.794	-7.784	-7.779	-7.785	-7.811
0.70	-6.933	-6.930	-6.926	-6.922	-6.919	-6.929	-6.952	-7.002
0.75	-6.155	-6.152	-6.149	-6.147	-6.149	-6.174	-6.213	-6.285
0.80	-5.458	-5.455	-5.453	-5.452	-5.461	-5.501	-5.555	-5.648
0.85	-4.826	-4.822	-4.820	-4.822	-4.839	-4.898	-4.969	-5.082
0.90	-4.238	-4.232	-4.230	-4.236	-4.267	-4.351	-4.442	-4.578
0.93	-3.894	-3.885	-3.884	-3.896	-3.941	-4.046	-4.151	-4.300
0.95	-3.658	-3.647	-3.648	-3.669	-3.728	-3.851	-3.966	-4.125