

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/Backlog), November 2017

B. Tech in Chemical Engineering, Semester III

Roll No.....

CHE305: Chemical Engineering Thermodynamics

Time: 3 hours

Max. Marks: 100

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A	Objective type multiple choice questions (10 questions @ 1 mark)	10																																																																					
i.	Volume expansivity of a pure substance is given by (a) $\beta = -\frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_P$ (b) $\beta = \frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_P$ (c) $\beta = V \left(\frac{\partial V}{\partial T} \right)_P$ (d) $\beta = \frac{1}{V} \left(\frac{\partial T}{\partial V} \right)_P$																																																																						
ii.	Given that the standard free energy of formation at 298K for NH3 is -16.75 KJ/mol, the standard Gibb's free energy change for the ammonia synthesis reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ is (a) -35.7 KJ (b) -33.5 KJ (c) -38.2 KJ (d) -53.4 KJ																																																																						
iii.	For a closed system, the difference between the heat added to the system and the work done by the system is equal to the change in (a) Enthalpy (b) Entropy (c) Temperature (d) Internal Energy																																																																						
iv.	The process is said to be feasible if (a) $\Delta G > 0$ (b) $\Delta G < 0$ (c) $\Delta G < 1$ (d) $\Delta G > 1$																																																																						
v.	Match List I with List II and select the correct answer using the codes given below the lists: <table><tr><th colspan="4">List I Parameter</th><th colspan="4">List II (Property)</th></tr><tr><td>A. Volume</td><td></td><td></td><td></td><td>1. Path Function</td><td></td><td></td><td></td></tr><tr><td>B. Density</td><td></td><td></td><td></td><td>2. Intensive Property</td><td></td><td></td><td></td></tr><tr><td>C. Pressure</td><td></td><td></td><td></td><td>3. Extensive Property</td><td></td><td></td><td></td></tr><tr><td>D. Work</td><td></td><td></td><td></td><td>4. Point Function</td><td></td><td></td><td></td></tr><tr><td>Codes:</td><td>A</td><td>B</td><td>C</td><td>D</td><td>A</td><td>B</td><td>C</td><td>D</td></tr><tr><td>(a)</td><td>3</td><td>2</td><td>4</td><td>1</td><td>(b)</td><td>3</td><td>2</td><td>1</td><td>4</td></tr><tr><td>(c)</td><td>2</td><td>3</td><td>4</td><td>1</td><td>(d)</td><td>2</td><td>3</td><td>1</td><td>4</td></tr></table>	List I Parameter				List II (Property)				A. Volume				1. Path Function				B. Density				2. Intensive Property				C. Pressure				3. Extensive Property				D. Work				4. Point Function				Codes:	A	B	C	D	A	B	C	D	(a)	3	2	4	1	(b)	3	2	1	4	(c)	2	3	4	1	(d)	2	3	1	4	
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vi.	The phase rule for a system can be written as (a) $F=C-P-1$ (b) $F = C-P+1$ (c) $F= C+P+2$ (d) $F=C-P+2$																																																																						

vii.	The efficiency of carnot engine working between 500K and 200K is (a) 80% (b) 75% (c) 60% (d) 70%	
viii.	The equilibrium criterion of a chemical reaction can be expressed as (a) $(dG)_{T,P} = 1$ (b) $(dG)_{T,P} = -1$ (c) $(dG)_{T,P} = 0$ (d) $(dG)_{T,P} = \infty$	
ix.	A carnot engine operates between 27°C and 327°C. If the engine produces 300KJ of work, what is the entropy change during heat addition? (a) 0.5 KJ/K (b) 1.0 KJ/K (c) 1.5KJ/K (d) 2.0 KJ/K	
x.	Enthalpy can be expressed as (a) $H = U - PV$ (b) $H - U = PV$ (c) $H = A - TS$ (d) $H - A = TS$	
Q.2	Short answer type questions (4 questions @ 2.5 marks)	10
(a)	Calculate the standard Gibbs free energy change and the equilibrium constant at 1 bar and 298K for the ammonia synthesis reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ Given that standard free energies of formation at 298K for NH_3 are -16.750 kJ/mol.	
(b)	Define Zeroth law of thermodynamics.	
(c)	Explain the Kelvin-Planck and Clausius statement of second law of thermodynamics.	
(d)	The saturation pressure of liquid water at 372.12K is 100 KPa. Estimate the fugacity of liquid water at 372.12K and 300 kPa, given that the molar volume of liquid water at 372.12K is $18.774 \times 10^{-6} \text{ m}^3/\text{mol}$.	
Q.3A	(a) State first law of thermodynamics. (b) A system undergoes a process in 1-2 in which it absorbs 100 kJ energy as heat and does 40 kJ work. Then the system follows the process 2-3 during which 30 kJ is rejected as heat while 50 kJ work is done on it. It is desired to restore the system to the initial state by an adiabatic path. Calculate (i) the work and heat interactions during the adiabatic process and (ii) the net work done and the net heat interaction.	02 + 03 = 05
Q.3B	Calculate the second and third virial coefficients of a gas which obeys van der waal's equation of state.	05
Q.4A	Explain the working principle of rankine cycle with the help of P-V diagram and T-S diagram.	05
Q.4B	35 kg of a steel casting at 725 K is quenched in 150 kg oil at 275K. if there are no heat losses, calculate the change in entropy. Data: C_P of steel = 0.88 kJ/(kg.K) and C_P of oil = 2.5 kJ/(kg.K)	05
Q.5	Carbon dioxide gas is sold commercially at 60 bar (6000 kPa). The gas is leaking through the outlet valve slowly, so that its temperature may be assumed constant at the ambient temperature of 27°C (300K).	05

	(i) Calculate the work done in the expansion of 0.227 kmol of CO₂ gas from 60 bar to 1 bar (100 kPa). (ii) If the temperature constant at 17°C (290K), what would be the work done? (iii) Find the changes in enthalpy in both the above cases.	
Q.6A	Derive the relation between temperature and volume for adiabatic process.	05
Q.6B	Estimate the equilibrium constant at 600K for the reaction $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ At 298 K: $\Delta G^\circ = -2030 \text{ kcal/mol}$ $\Delta H_f^\circ \text{ for: } H_2O(g) = -57798 \frac{\text{cal}}{\text{mol}}$ $C_2H_5OH(g) = -56240 \frac{\text{cal}}{\text{mol}}$ $C_2H_4(g) = 12496 \frac{\text{cal}}{\text{mol}}$ $R = 1.987$ OR	05
Q.6B	Calculate the equilibrium constant at 1000 K and 1 bar for the following reaction: $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$ Assuming that the heat of reaction remains constant in the temperature range involved. Given that equilibrium constant K at 298K and 1 bar is 1.1582×10^5. $\Delta H_{f,CO}^\circ = -110.532 \text{ kJ}$ $\Delta H_{f,H_2O}^\circ = -241.997 \text{ kJ}$ $\Delta H_{f,CO_2}^\circ = -393.978 \text{ kJ}$	05
Q.7A	Write short note on: (a) Chemical potential (b) Activity (c) Fugacity (d) Residual property	05
Q.7B	Estimate the fugacity of a gaseous mixture consisting of 30 mol% component 1 and 70% component 2 by mole, given that at 100°C and 50 bar, the fugacity coefficients of components 1 and 2 are 0.7 and 0.85.	05
	OR	
Q.7B	Show that $\left(\frac{\partial U}{\partial P}\right)_T = -\left[T\left(\frac{\partial V}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial P}\right)_T\right]$	05
Q.8A	Prove that van der waals constants (a,b) can be expressed in terms of critical temperature and pressure as follows: $a = \frac{27R^2T_c^2}{64P_c} \qquad b = \frac{RT_c}{8P_c}$	15
Q.9A	Derive Maxwell's relation among thermodynamics properties.	10

Q.9B	(a) Explain the vapour-liquid equilibrium for a binary system by discussing the Temperature-Composition (T-x-y) Diagram and Pressure--Composition (P-x-y) Diagram. (b) A binary liquid mixture consists of 60 mol percent ethylene and 40 mol percent propylene. At 423K, the vapour pressure of ethylene and propylene are 15.2 atm and 9.8 atm respectively. Calculate the total pressure and equilibrium composition of the vapour phase. Assume that the mixture behaves like an ideal solution.	07 + 03 = 10
OR		
Q.9B	(a) Explain the working principle of Carnot cycle with the help of a P-V diagram. (b) A carnot engine working between a high temperature source at 373K and a low-temperature sink at 275K receives 50KJ of heat from a high-temperature region. Determine: (i) The minimum work required (ii) the efficiency (iii) The amount of heat released.	05 + 05 = 10

***** GOOD LUCK *****