14CH404

Hall Ticket Number:

II/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

April, 2017 — **Chemical Engineering**

Fourth Semester — **Engineering Thermodynamics**

Time: Three Hours — **Maximum :** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1**.** Answer the following (12X1=12 M)

a.	Internal energy: Submolecular energy; Inter-atomic and intra atomic energy; Translational, rotational and vibrational energies of molecules, bonding energy, potential energy of electrons and nuecleons;
b.	Intensive property: Quantity independent property; Molar energies like U, H,G and A
c.	Reversible process: Direction can be revered by an infinitismal change in driving force; is frictionless; Never more than differentially removed from equilibrium position; Traverses a succession of equilibrium positions; driven a force whose imbalance is infinitismal in magnitude; When reversed, retraces its forward path, and restores the initial state of system and Surroundings;
d.	Cyclic process: process that periodically retains it's original state.
e.	Entropy: There exists a property called entropy S, which is an intrinsic property of a system, functionally related to the measurable coordinates which characterize the system. For a reversible process dQ = TdS
f.	Third law of thermodynamics: Absolute entropy of a pure crystalline substance at 0 K is zero.
g.	Adiabatic mixing process: Mixing without heat exchange with surroundings;
h.	Clausius inequality: dQ = TdS for reversible change; and dQ < TdS for an irreversible change;
i.	Throttling process: dH=0; it is sudden expansion through a porous plug or valve or so on….
j.	Equation of state: f(p,v,T)=0;
k.	Gibbs free energy: G=H-TS
l.	Liquefaction : Changing the state of substance to liquid.

UNIT I

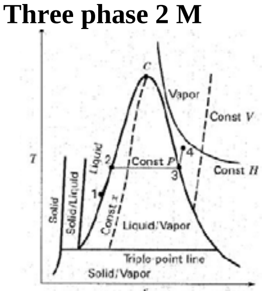
2	a.	Discuss in brief heat and work: Heat is a form of energy under transit due to temperature difference; Work is defined as product of distance and force in the direction of motion; As both are different forms of energy only they enjoy same units of Joules in SI system and they are inter convertible. According Joule's experiment work could be converted completely in to heat and heat energy is stored in substance in the form of internal energy; 1 Cal of heat = 4.187 J is known as mechanical equivalence of heat; But according to second law of TD heat cannot be completely converted in to work continuously. **2x3 = 6 M**	6M	
	b.	A car of 1000 kg mass is moving with a speed of 90 km/h on a road. This is 100m above sea level. Calculate the kinetic energy and potential energy of the car. K.E = 0.5x1000x25x25 = 312.5 kJ; P.E= 1000x9.8x100 = 980 kJ; **KE = 3 M; PE = 3 M**	6M	
(OR)				
3	a.	Compare and contrast the characteristics of control mass and control volume: Control mass means constant mass system or closed system; Control volume system means constant volume system or open system; Former one exchanges only energy with surroundings; Later one can exchange both mass and energy with surroundings. The basis of analyzing open system is closed system only. PV energy and external shaft work are also considered in case of flow process. **2.5 M + 2.5 M**	5M	
	b.	A system is taken from state1 to state 2 along path A. During this process it received 200KJ energy as heat and does 100KJ work. If the system is taken from state2 to state1 by a different path B, it is necessary to spend 150KJ of work on the system. Determine the heat interaction along the path B. Suppose the system is restored to state1 from state2 by an adiabatic path C, how much work has to be done on the system: Path A: 200-100 = 100 kJ = ΔU; 150+Q = -100 = > Q = -250 kJ; Means heat is given away by system; 0 + W = -250 kJ;**3 M + 2 M + 2 M**	7M	

UNIT II

4		Air is compressed from an initial condition of 1 bar and 25 ^{0}C to a final state of 5 bar and 25^{0}C by two different mechanically reversible processes in a closed system.	6M	

		i) Heating at constant volume followed by cooling at constant pressure: Heating at constant volume is done up to a temperature of 125 C; Therefore W = 0; Q = ΔU = 2.5R x 100 J/mol; ΔH = 3.5R x 100 J/mol; Cooling at constant pressure: Q=ΔH = $3.5Rx - 100\frac{J}{mol}$; W= - R(-100) J/mol; $\Delta U = 2.5\ R\ (-100)$ J/mol; **3 M + 3 M** ii) Adiabatic compression followed by cooling at constant volume: Adiabatic Compression: $\frac{T_2}{T_1} = \left(\frac{5T_2}{298.15}\right)^{\frac{1.4}{0.4}} => T_2 = 567.15\ K$; $W = \frac{R(567.15-298.15)}{0.4} = 672.5\ R$ J/mol; ΔU = 2.5R x 269 J/mol; ΔH = 3.5R x 269 J/mol ;Q = 0 J/mol; Constant volume step: W = 0 J/mol; $Q = \Delta U$ = 2.5R x -269 J/mol; ΔH = 3.5R x − 269 J/mol; **3 M + 3 M** Assume air as ideal gas with constant heat capacities ,Cv =(5/2)R and Cp = (7/2)R , Calculate Q,W ΔU and ΔH for each of the process	6M	
		(OR)		
5	a.	Significance of Virial equation of state of cubic equations of state, write its expression and what is the significance of a,b in Van der wall equation of state: Virial EOS is applicable to vapor/gas/fluid phase only; In general cubic EOS are applicable to both liquid and vapor phases. $z = 1 + \frac{B}{V} + \frac{C}{V^2}$ or $z = 1 + bP + cP^2$ where B, C and b, c are called second and third virial coefficients. Virial means force in latin. Both second and third virial coefficients are functions of both temperature and nature of species. a and b parameter of van Der Waals EOS for pressure and volume both a and b are function of critical constants; **2 M + 3 M + 2 M**	7M	
	b.	On a PV diagram the slope of reversible adiabatic line and the slope of reversible isothermal line are related as? Slope on adiabatic curve = -γ slope of PV curve on isothermal curve $\ln P + \gamma \ln V = \ln C => \left(\frac{\partial P}{\partial v}\right)_T = \gamma\left(-\frac{P}{V}\right)$; **3 +2 = 5 M**	5M	

UNIT III

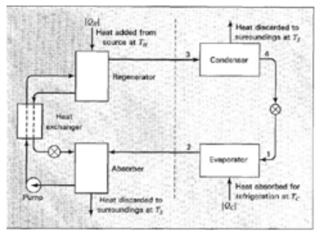
6	a.	Show that the following for an ideal gas i) $\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$: $\left(\frac{\partial V}{\partial T}\right)_P = \frac{R}{P}$ since v = RT/P $-\left(\frac{\partial S}{\partial P}\right)_T = \frac{R}{P}$; since ds^{ig} = -(R/P)dP at const.T ii) $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$ for an ideal gas $dU = Tds - pdv => ds^{ig} = \frac{C_v^{ig}}{R}\frac{dT}{T} + \frac{dV}{V} => \left(\frac{\partial T}{\partial V}\right)_S = -\frac{RT}{C_v^{ig}v}$; Also $dU = Tds - pdv => -\left(\frac{\partial s}{\partial P}\right)_V = -\frac{C_v^{ig}}{T}\left(\frac{\partial T}{\partial P}\right)_v = -\frac{C_v^{ig}}{RT}v$; $\therefore -\left(\frac{\partial P}{\partial s}\right)_V = -\frac{RT}{C_v^{ig}v}$ **3 M + 3 M**	6M	
	b.	Draw T-S diagram and clearly identify single phase and two phase regions and three phase regions **fig 2 M + two phase 2 M + Three phase 2 M** 	6M	
		(OR) **14CH404**		
7		Derive an expression to for critical pressure ratio For rev.adiabatic process for an ideal gas….$PV^\gamma = Const$ $udu = -Vdp => u_2^2 - u_1^2 = -2\int_{P_1}^{P_2} Vdp = -2\int_{P_1}^{P_2}\left(\frac{Const}{P}\right)^{\frac{1}{\gamma}} dp = \frac{-2\gamma}{\gamma-1}Const^{\frac{1}{\gamma}}\left[P_2^{-\frac{1}{\gamma}+1} - P_1^{-\frac{1}{\gamma}+1}\right]$ $= \frac{2\gamma}{\gamma-1}\left(Const^{\frac{1}{\gamma}}\right)\left(P_1^{-\frac{1}{\gamma}+1}\right)\left[1 - P_2^{-\frac{1}{\gamma}+1}/P_1^{-\frac{1}{\gamma}+1}\right] = \frac{2\gamma}{\gamma-1}P_1V_1\left[1 - P_2^{-\frac{1}{\gamma}+1}/P_1^{-\frac{1}{\gamma}+1}\right]$ **6 M** But if flow in throat is sonic (u= c) ∴ $u_2^2 = c^2 = -V^2\left(\frac{\partial P}{\partial V}\right)_S = \gamma P_2 V_2$ If $u_1 = 0$; $u_2^2 - 0 = \gamma P_2 V_2 = \frac{2\gamma}{\gamma-1}P_1V_1\left[\frac{1-P_2^{-\frac{1}{\gamma}+1}}{P_1^{-\frac{1}{\gamma}+1}}\right] = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{2\gamma}{\gamma-1}\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right] \Longrightarrow$	12M	

$\frac{P_2}{P_1} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$ **6 M**

UNIT IV

8 Explain the following with neat diagram **(fig 2 M + Des 2 M + Eg/COP = 2 M)**

a. Absorption refrigeration: Absorption refrigeration cycle is similar to the vapor compression refrigeration cycle only, except the way vapor compression is achieved. In this cycle vapor from evaporator is absorbed in a relatively nonvolatile solvent at evaporator pressure and at lower temperature level of heat engine. Heat of absorption is rejected to surroundings. This is heat rejected by the engine. The liquid solution from the absorber, which contains a relatively high concentration of refrigerant, passes to a pump, which raises the pressure of the liquid to that of the condenser. Heat from the higher temperature source at T_H is transferred to the compressed liquid solution, raising its temperature and evaporating the refrigerant from the solvent. Vapor passes from the regenerator to the condenser, and solvent, which now contains a relatively low concentration of refrigerant, returns to the absorber. The heat exchanger conserves energy and also adjusts stream temperatures toward proper values. Low-pressure steam is the usual source of heat for the regenerator.



The most commonly used absorption-refrigeration system operates with water as the refrigerant and a lithium bromide solution as the absorbent. This system is obviously limited to refrigeration temperatures above the freezing point of water. For lower temperatures ammonia can serve as refrigerant with water as the solvent. An alternative system uses methanol as refrigerant and polyglycolethers as absorbent.

6M
6M

Consider refrigeration at a temperature level of T_C = 263.15 K with a heat source of condensing steam at atmospheric pressure T_H = 373.15 K. For a surroundings temperature of T_S = 303.15 K, the minimum possible value of $|Q_H|/|Q_C| = \left(\frac{373.15}{373.15-303.15}\right)\left(\frac{303.15-263.15}{263.15}\right) = 0.81$. Actual value will be about three times this.

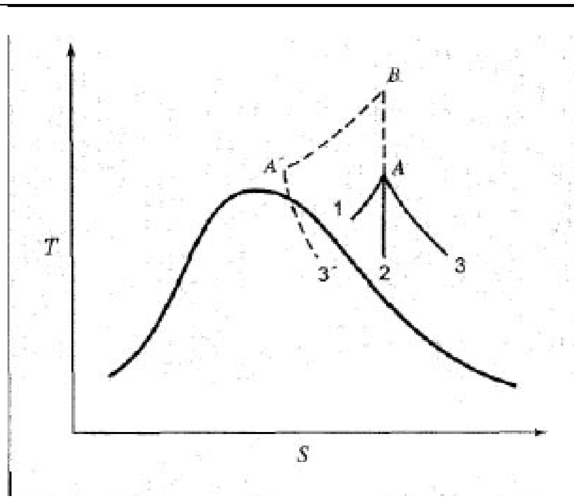
b. **liquefaction process**

Liquefied gases are in common use for a variety of purposes. For example, liquid propane in cylinders serves as a domestic fuel, liquid oxygen is carried in rockets, natural gas is liquefied for ocean transport, and liquid nitrogen is used for low-temperature refrigeration. In addition, gas mixtures (e.g., air) are liquefied for separation into their component species by fractionation.

Liquefaction results when a gas is cooled to a temperature in the two-phase region. This may be accomplished in several ways

1. By heat exchange at constant pressure.
2. By an expansion process from which work is obtained.
3. By a throttling process.

The first method requires a heat sink at a temperature lower than that to which the gas is cooled, and is most commonly used to pre-cool a gas prior to its liquefaction by the other two methods. An external refrigerator is required for a gas temperature below that of the surroundings.



The constant-pressure process (1) approaches the two-phase region (and liquefaction) most closely for a given drop in temperature. The throttling process (3) does not result in liquefaction unless the initial state is at a high enough pressure and low enough temperature for the constant-enthalpy process to cut into the two-phase region. This does not occur when the initial state is at A. If the initial state is at A', where the temperature is the same but the pressure is higher than at A, then isenthalpic expansion by process (3') does result in the formation of liquid. The change of state from A to **A'** is most easily accomplished by compression of the gas to the final pressure at B, followed by constant-pressure cooling to A'. Liquefaction by isentropic expansion along process (2) may be accomplished from lower pressures (for given temperature) than by throttling.

The throttling process (3) is the one commonly employed in small-scale commercial liquefaction plants. The temperature of the gas must of course decrease during expansion. This is indeed what happens with most gases at usual conditions of temperature and pressure. The exceptions are hydrogen and helium, which increase in temperature upon throttling unless the initial temperature is below about 100 K for hydrogen and 20 K for helium. Liquefaction of these gases by throttling requires initial reduction of the temperature to lower values by method 1 or 2.

for air shows that at a pressure of 100 atm the temperature must be less than 169 K for any liquefaction to occur along a path of constant enthalpy. **3 x 2 = 6 M**

(OR)

9	a	Write a short notes on heat pump The heat pump, a reversed heat engine, is a device for heating houses and commercial buildings during the winter and cooling them during the summer. In the winter it operates so as to absorb heat from the surroundings and reject heat into the building. Refrigerant evaporates in coils placed underground or in the outside air; vapor compression is followed by condensation, heat being transferred to air or water, which is used to heat the building. Compression must be to a pressure such that the condensation temperature of the refrigerant is higher than the required temperature level of the building. The operating cost of the installation is the cost of electric power to run the compressor. If the unit has a coefficient of performance, $Q_C/W = 4$, the heat available to heat the house I QH I is equal to five times the energy input to the compressor. Any economic advantage of the heat pump as a heating device depends on the cost of electricity in comparison with the cost of fuels such as oil and natural gas. The heat pump also serves for air conditioning during the summer. The flow of refrigerant is simply reversed, and heat is absorbed from the building and rejected through underground coils or to the outside air. **Fig 2 M + COP = 2 M; Description = 2 M**	5M
	b	A refrigerator requires 1kw of power per ton of refrigeration. What is the coefficient of performance and how much of heat is rejected in the condenser. Ton of refrigeration = 3.51 kW; COP = 3.51/1 = 3.51; Heat rejected = 4.51 kW **(2 M + 2 M + 3 M)**	7M

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