Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

B.E. Sem.-III (Biotechnology) Examination December 2009

Subject code: 130405 **Subject Name: Thermodynamics**

Date: 29 /12/ 2009 **Time: 11.00 am – 1.30 pm**

Total Marks: 70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Notations used have their conventional meanings.**

Q.1 **(a)** Explain PVT behavior of pure substances with the help of PT and PV diagrams. **07**

(b) Derive a mathematical expression of the first law of thermodynamics for a steady state flow process between a single entrance and a single exit. **07**

Q.2 **(a)** Handbook values for the latent heat of vaporization in J/g are given in the table for the pure liquids at T_n, the normal boiling point. **07**

Component	ΔH^{lv} at T_n (J/g)	T_n (K)	P_c (bar)	T_c (K)
Benzene	393.9	353.2	48.98	562.2
Toluene	363.2	383.8	41.06	591.8

For these substances, calculate the value of the latent heat at T_n by Riedel equation and find out the percentage difference from those listed in the table.

(b) A particular quantity of an ideal gas $C_v = (5/2)\,R$ undergoes the following mechanically reversible steps that together form a cycle. The gas, initially at 1 bar and 300 K, is compressed isothermally to 3 bar. It is then heated at constant P to a temperature of 900 K. Finally; it is cooled at constant volume to its initial state with the extraction of 1,300 J as heat. Determine Q and W for each step of the cycle and for the complete cycle. **07**

OR

(b) Nitrogen gas is confined in a cylinder and the pressure of the gas is maintained by a weight placed on the piston. The mass of the piston and the weight together is 100 kg. The acceleration due to gravity is 9.81 m/s^2 and the atmospheric pressure is 1.01325 bar. Assume frictionless piston. Determine: **07**

i) The force exerted by the atmosphere, the piston and the weight on the gas if the piston is 200 mm in diameter.

ii) The pressure on the gas.

iii) If the gas is allowed to expand pushing up the piston and the weight by 500 mm, what is the work done by the gas in kJ?

Q.3 **(a)** If the heat capacity of a substance is correctly represented by an equation of the form, $Cp = A + BT + CT^2$, show that the error resulting when $\langle Cp \rangle_H$ is assumed equal to Cp evaluated at the arithmetic mean of the initial and final temperatures is $C(T_2 - T_1)^2 / 12$. **05**

(b) A special manometer fluid has a specific gravity of 3.65 and is used to measure a pressure of 1.25 bar at a location where the barometric pressure is 760 mm Hg. What height will the manometer fluid register? **05**

	(c)	How much heat is required when 200 g of $CaCO_3$ is heated at atmospheric pressure from 30°C to 700°C? Data: $Cp/R = 12.572 + 2.637 \times 10^{-3}T - 3.12 \times 10^{5}T^{-2}$, T is in K	**04**

OR

Q.3	**(a)**	Water at 368 K is pumped from a storage tank at the rate of 25 m^3/h. The motor for the pump supplies work at the rate of 2 hp. The water passes through a heat exchanger, where it gives up heat at the rate of 42000 kJ/min and is delivered to a second storage tank at an elevation of 20 m above the first tank. What is the temperature of the water delivered to the second storage tank? Assume that the enthalpy of water is zero at 273 K and the specific heat of water is constant at 4.2 kJ / kg K.	**07**
	(b)	The vapour pressures of acetone (1) and acetonitrile (2) can be evaluated by the following Antoine equations:	**07**

$$\ln p_1^{sat}\ (kPa) = 14.5463 - \frac{2940.46}{T\ (K) - 35.93}\ ;\ \ln p_2^{sat}\ (kPa) = 14.2724 - \frac{2945.47}{T\ (K) - 49.15}$$

Assuming the validity of Raoult's Law, calculate:
i) P and y_1 at T = 327 K and x_1 = 0.4.
ii) T and x_1 at P = 65 kPa and y_1 = 0.4.

Q.4	**(a)**	Derive the equation for entropy change (ΔS) for an ideal gas.	**08**
	(b)	For an Ideal gas with constant heat capacities, show that … (i) For a temperature increase from T_1 to T_2, ΔS of the gas is greater when the changes occurs at constant pressure than when it occurs at constant volume. (ii)For a pressure change from P_1 to P_2, the sign of ΔS for an Isothermal change is opposite that for a constant-volume change.	**06**

OR

Q.4	**(a)**	Describe both types of vapor compression refrigeration cycle with the help of neat diagrams.	**07**
	(b)	For the ammonia synthesis reaction written	**07**

$$\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \rightarrow NH_{3(g)}$$

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

$$\varepsilon_e = 1 - (1 + 1.299\ KP)^{-1/2}$$

Q.5	**(a)**	For the two-phase systems, derive the Clausius / Clapeyron equation relating latent heat of vapourization directly to the vapour-pressure curve.	**04**
	(b)	A steel casting [C_p=0.5 kJ kg^{-1} K^{-1}] weighing 40 kg and at a temperature of 450°C is quenched in 150 kg of oil [C_p=2.5 kJ kg^{-1} K^{-1}] at 25°C. If there are no heat losses, what is the change in entropy of (i) the casting (ii) the oil, and (iii) both considered together?	**06**
	(c)	Explain the concept of volume expansivity, 'β' and isothermal compressibility, 'k' for liquids.	**04**

OR

Q.5	**(a)**	Explain the term 'temperature'. Mention different units of temperature and relations among various temperature scales with diagrams.	**05**
	(b)	A system consisting of some fluid is stirred in a tank. The rate of work done on the system by the stirrer is 2.25 hp. The heat generated due to stirring is dissipated to the surroundings. If the heat transferred to the surroundings is 3400 kJ/h, determine the change in internal energy.	**05**
	(c)	Derive the following Maxwell's equation from the first principle:	**04**

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

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