

Exam. Code: 0908  
Sub. Code: 6702

1019

B.E. (Biotechnology) Fourth Semester  
BIO-412: Thermodynamics

Time allowed: 3 Hours

Max. Marks: 50

**NOTE:** Attempt five questions in all, including Question No. 1 which is compulsory and selecting two questions from each Section. Assume missing data, if any, reasonably.

x-x-x

- I
- i. What is Gibbs phase rule for a nonreactive system? 10×1
  - ii. Define activity coefficient.
  - iii. Define partial molar properties.
  - iv. What is chemical potential?
  - v. What is enthalpy of a system? How is it related to internal energy?
  - vi. When muscles contract, chemical energy is converted to mechanical energy with the loss of heat. Define the law of thermodynamics which this example represents.
  - vii. Which molecule is considered to be the energy currency of cells?
  - viii. What is inversion temperature?
  - ix. Give examples of intensive and extensive properties.
  - x. A container filled with a sample of an ideal gas at the pressure of 1.5 atm. The gas is compressed isothermally to one-fourth of its original volume. What is the new pressure of the gas?

Section A

- II
- (a) If a gas of volume  $6000 \text{ cm}^3$  and at a pressure of 100 kPa is compressed quasistatically according to  $PV^2 = \text{constant}$ , until the volume becomes  $2000 \text{ cm}^3$ , determine the final pressure and the work transfer. 4
  - (b) 2 kilo mole of  $\text{CO}_2$  occupies a volume of  $0.380 \text{ m}^3$  at 313 K. Calculate the pressure using ideal gas equation and van der Waals equation. Take van der Waals constants to be  $a = 0.365 \text{ Nm}^4/\text{mol}^2$  and  $b = 4.28 \times 10^{-5} \text{ m}^3/\text{mol}$ . 6
- III
- (a) What is the principle of operation of an absorption refrigeration system? 3
  - (b) Explain the Claude process for the liquefaction of air. Derive an expression for the liquid yield obtained from the process. 7
- IV
- One mole of ideal gas, initially at  $150^\circ\text{C}$  and 8 bar pressure, undergoes the following mechanically reversible changes: It expands isothermally to a pressure such that when it is cooled at constant volume to  $50^\circ\text{C}$  its final pressure is 3 bar. Calculate the work, heat transferred, changes in internal energy and changes in enthalpy for the process. Take  $C_p = (7/2)R$  and  $C_v = (5/2)R$ . 10

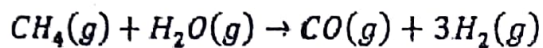
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Section B

- V (a) Initially  $n_0$  moles of ammonia are present which dissociate according to the equation  $NH_3 \leftrightarrow \frac{1}{2} NH_2 + \frac{3}{2} H_2$ . Show that at equilibrium  $K = \frac{\sqrt{27}}{4} \frac{\epsilon^2}{1-\epsilon^2} P$ .
- (b) The enthalpy of a binary liquid system for species 1 and 2 at fixed Temperature (T) and pressure (P) is given by equation  $H = x_1 x_2 (40x_1 + 20x_2)$  where H is in J/mole. Determine expression for  $\bar{H}_1$  and  $\bar{H}_2$  as a function of  $x_1$ , and the numerical values for the partial enthalpies at infinite dilution  $\bar{H}_1^\infty$  and  $\bar{H}_2^\infty$ .

- VI An equimolar mixture of  $CH_4(g)$  and  $H_2O_2(g)$  enters a reactor which is maintained at 1000K and 5 bar. The following reaction takes place



Calculate the equilibrium constant at 1000 K and estimate the degree of conversion of methane into products. Also estimate the composition of the reactor effluent assuming that the reaction mixture behaves like an ideal gas.

$$C_p = a + bT + cT^2 + dT^3 + eT^{-2} \text{ (J/mol K)},$$

$$\Delta H_{rxn}^\circ = 206.408 \text{ kJ}, \Delta G_{rxn}^\circ = 141.933 \text{ kJ}$$

$$C_{pCO} = 28.068 + 4.631 \times 10^{-3}T - 0.258 \times 10^5 T^{-2}$$

$$C_{pH_2} = 27.012 + 3.509 \times 10^{-3}T + 0.690 \times 10^5 T^{-2}$$

$$C_{pCH_4} = 17.449 + 60.449 \times 10^{-3}T + 1.117 \times 10^{-6}T^2 - 7.204 \times 10^{-9}T^3$$

$$C_{pH_2O} = 28.850 + 12.055 \times 10^{-3}T + 0.690 \times 10^5 T^{-2}$$

- VII Binary system Acetonitrile (1)/Nitromethane (2) conforms closely to Raoult's law. Vapor pressure for the pure species are given by the following Antoine equations:

$$\ln P_1^{sat} (\text{kPa}) = 14.2724 - \frac{2945.47}{t(^{\circ}C) + 224}$$

$$\ln P_2^{sat} (\text{kPa}) = 14.2043 - \frac{2972.64}{t(^{\circ}C) + 209}$$

Prepare a t-x-y diagram for a pressure of 70kPa.