Code: 9A23404 1

B.Tech II Year II Semester (R09) Regular & Supplementary Examinations, April/May 2013

THERMODYNAMICS IN BIOPROCESS SYSTEMS

(Biotechnology)

Time: 3 hours Max. Marks: 70

Answer any FIVE questions

All questions carry equal marks

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1 One Kg of water (V1 = 1003 cm^3/kg) in a piston cylinder device at 25℃ and 1 bar is compressed in a mechanically reversible isothermal process to 500 bar. Determine Q, WΔU, ΔH and ΔS given $\beta = 250 \times 10^{-6} K^{-1}$ and $K = 45 \times 10^{-6} bar^{-1}$.

2 (a) Sketch a Carnot cycle on a T-S diagram and discuss briefly.
(b) Determine the maximum possible efficiency of a heat engine working between two thermal reservoirs with temperatures 327℃ and 27℃.

3 (a) Name the two conditions, which every equation of state should satisfy.
(b) What are the units of the Van der Waals constants a and b.

4 From the residual property relations show that;

$$\frac{G^R}{RT} = \int_0^P (Z_f - 1)\frac{dP}{P}$$

5 Prove that:
(a) $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$
(b) $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$

6 Describe about SLE and VLLE with neat diagrams.

7 (a) Define chemical potential of a component in the mixture. Discuss the importance of chemical potential.
(b) Define partial molar property, Mi of a species in solution. Show that the chemical potential and partial molar Gibbs energy are identical.

8 (a) What is equilibrium constant?
(b) What is effect of temperature on equilibrium constant?

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1 (a) Define any two of the following:
(i) Energy (ii) Property
(iii) Work (iv) Equilibrium.
(b) Differentiate between intensive and extensive properties with suitable examples.

2 The following heat engines produce power of 95000 kW. Determine in each case the rates at which heat is absorbed from the hot reservoir and discarded to the cold reservoir.
(a) A Carnot engine operates between heat reservoirs at 750 K and 300 K.
(b) A practical engine operates between the same heat reservoirs but with a thermal efficiency η = 0.35.

3 Write short notes on:
(a) Two forms of virial equation.
(b) Ideal gas behavior.
(c) Simplified property relations for an ideal gas.

4 (a) Define Helmholtz free energy and Gibbs free energy.
(b) Discuss various thermodynamic diagrams and tables used for estimation of thermodynamic properties.

5 Prove that:
(a) $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$
(b) $\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial V}\right)_T$

6 (a) Explain the V-L-E concept with a T-x-y diagram.
(b) How the VLE data of a binary mixture can be calculated using equation of state.

7 (a) Define partial molar property.
(b) Derive Gibbs-Duhem equation.

8 Rate and equilibrium conversion of a chemical reaction depends on what parameters. How rate and equilibrium conversion varies in various situations? Give a suitable example to explain above.

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1 (a) State the condition for thermal equilibrium between two given systems.
(b) How do we classify a process as reversible or irreversible?

2 A Carnot engine operates between temperature levels of 600 K and 300 K. It drives a Carnot refrigerator, which provides cooling at 250 K and discards heat at 300 K. Determine a numerical value for the ratio of heat extracted by the refrigerator ("cooling load") to the heat delivered to the engine ("heating load").

3 If one kmol of methane is stored in a 0.3 m^3 tank at 300 K, estimate the pressure of the gas using Redlich-Kwong equation of state. The critical constants of methane are $P_C = 4.6 \times 10^6$ Pa and $T_C = 190.6$ K.

4 (a) Discuss chemical potential as a criterion for phase equilibrium.
(b) Define the following partial molar properties:
Internal energy, Enthalpy, Entropy, Gibbs energy.

5 Prove that:
(a) $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$
(b) $\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$

6 What are the criteria for liquid equilibrium? Discuss LLE with solubility diagrams.

7 Show that when Lewis Randall rule is valid for one species in a binary solution, Henry's law is valid for the other species.

8 (a) Explain the temperature dependency of the equilibrium constant of a reaction.
(b) Determine the equilibrium constant at 25℃ for the reaction

CH4 (g) + H2O(l) – – – – -> CO(g) + 3H2(g).

Component	$\Delta G°_f$ at 250 C
CO (g)	-32.81 kcal/gmol
CH4 (g)	-12.14 kcal/gmol
H2O (l)	-56.7 kcal/gmol

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1 (a) What is the significance of joules experiment in the formulation of the first law of thermodynamics?

(b) What do you mean by cyclic process? State and explain the first law for a cyclic process.

2 (a) Discuss about general statements of second law of thermodynamics.

(b) It is required to freeze 1 kg of water at 273 K by means of refrigeration machine with the surroundings at 300 K. The latent heat of fusion at 273 K is 335 kJ/kg.
Determine:
(i) The minimum amount of work required.
(ii) The heat given up to the surroundings.

3 Write short notes on:

(a) Vander walls equation of state.

(b) Generic cubic equation of state.

4 What is fugacity coefficient and derive;

$$\ln\varphi_i = \int_0^P \left(Z_f - 1\right)\frac{dP}{P}$$

5 Drive any two Maxwell's equations.

6 Discuss the qualitative behavior of VLE using a three dimensional diagram.

7 For the ideal solution show that:

(a) $G^{id} = \sum_i x_i G_i + RT \sum_i x_i Inx_i$

(b) $S^{id} = \sum_i x_i S_i + R \sum_i x_i Inx_i$

8 For chemical reactions show that:

(a) $K = exp\left[\frac{-\Delta G^{\circ}}{RT}\right]$

(b) $\Delta H^{\circ} = RT^V \frac{d\left(\frac{\Delta G^{\circ}}{RT}\right)}{dT}$

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