Problem 1 (20%)

(a) Using the Maxwell relations, determine a relation for $(\partial s/\partial v)_T$ for a gas whose equation of state is

$$P=\frac{RT}{v-b}-\frac{a}{v^2T}. \text{ (10\%)}$$

(b) What is the Boyle temperature? (10%)

Problem 2 (10%)

(a) If the pressure in an isentropic process is raised, does the enthalpy go up or down? (5%)

(b) Is that independent upon the phase? (5%)

Problem 3 (10%)

An air-conditioner provides 1 kg/s of air at 15°C cooled from outside atmospheric air at 35°C. Estimate the amount of power needed to operate the air-conditioner. Clearly state all assumptions made. (10%)

Problem 4 (10%)

An approximation for the saturation pressure can be $\ln P_{sat} = A - B/T$, where $A$ and $B$ are constants. Which phase transition is that suitable for, and what kind of property variations are assumed? (10%)

Problem 5 (27%)

(a) Describe the physical meanings and SI units for the terms, $v_0$, $k_{cat}$, $C_{ET}$, $C_S$, and $K_M$, respectively in the Michaelis-Menten equation as given below. (10%)

$$v_0=\frac{k_{cat}C_{ET}C_S}{K_M+C_S}$$

(b) Describe the mechanism differences between (i) competitive inhibition, (ii) noncompetitive inhibition, and (iii) uncompetitive inhibition in enzyme kinetics. (6%)

(c) Compare the kinetic characteristics of competitive inhibition with those of noncompetitive inhibition by "the Lineweaver–Burk plot ($1/v_0$ *vs.* $1/C_S$)." (4%)

(d) Derive the rate equation for an enzymatic reaction under uncompetitive inhibition, and prove that $k_{cat}/K_M$ remains unchanged after introducing the uncompetitive inhibitor into the enzymatic reaction. (7%)

Problem 6 (23%)

(a) Derive the design equation for a plug-flow reactor (PFR) carrying out an isothermal first-order homogeneous reaction and describe how to determine the space time ($\tau$) for a PFR with a given volume (V) and a desired conversion (X). (8%)

(b) By analogy to (a), derive the design equation for a packed-bed enzyme reactor carrying out a simple enzyme reaction that is govern by the Michaelis-Menten equation. (8%)

(c) Describe briefly how to determine $k_{cat}$ and $K_M$ empirically according to (b)? And what factors may cause the deviations of $k_{cat}$ and $K_M$ measured from the theoretical values? (7%)

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