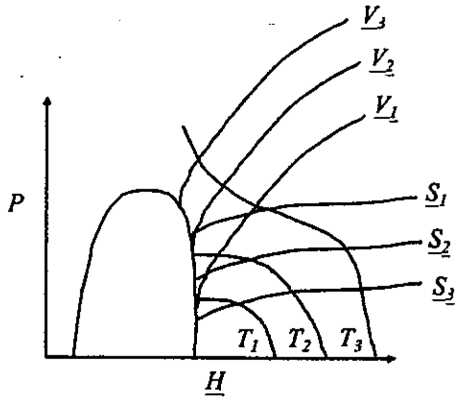
Part I Short-Answer Questions (30 points)

1. What is the gas-hourly space velocity (GHSV)? (3 points)
2. What is the turnover frequency (TOF)? (3 points)
3. What is the rate-limiting step? (3 points)
4. What is the parallel reaction? (3 points)
5. What is the design equation for well-mixed "fluidized" catalytic bed reactor? (3 points)
6. The internal energy (*U*) remains constant in the isothermal process in a closed system. (Ture or False?) (2 points)
7. Steam quality is defined as the ratio of vapor mass to liquid mass. (Ture or False?) (2 points)
8. For an ideal gas, the efficiency of a Carnot cycle will not be 100% even if a reversible process is formed. (Ture or False?) (2 points)
9. Which process does the Joule-Thomson process refer to? An isobaric process, an adiabatic process, an isenthalpic process, or an isochoric process? (2 points)
10. "Fugacity" is a measure of the difference in molar Gibbs free energy between a real fluid and an ideal fluid, and "Fugacity coefficient" is a measure of the molar Gibbs energy of a real fluid. (Ture or False?) (2 points)
11. On the below P-$\underline{H}$ diagram, isotherms ($T_1 < T_2 < T_3$), isochores ($V_1 < V_2 < V_3$), and isentropes ($S_1 < S_2 < S_3$) are shown. Is this figure consistent with requirements for a stable equilibrium system? Why? (5 points)



Part II Derivation and Calculation Questions (70 points)

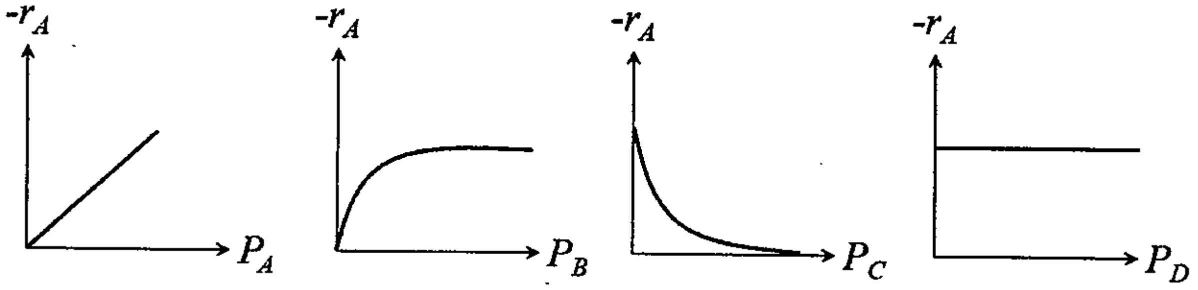
12. An enzyme-catalyzed reaction is described by the following mechanism:

$$E+S\xrightarrow{k_1}E\cdot S \qquad E\cdot S\xrightarrow{k_2}E+S \qquad E\cdot S\xrightarrow{k_3}P+E$$

$$E\cdot S+I\xrightarrow{k_4}I\cdot E\cdot S \qquad I\cdot E\cdot S\xrightarrow{k_5}E\cdot S+I$$

where *E*, *S*, *I*, and *P* are the enzyme, substrate, inhibitor, and product, respectively; *E*·*S*, and *I*·*E*·*S* are the complex formed between *E*, *S*, and *I*. The total enzyme concentration is $[E_t]$.
Please derive the rate expression for the disappearance of substrate ($-r_s$) in the form for the Lineweaver-Burk plot. (15 points)

13. A gas-phase reaction ($A+B\rightarrow C+D$) is catalyzed by a solid catalyst isothermally. The disappearance rates of species *A* were measured with varying partial pressures of species *A*, *B*, *C*, and *D* as shown in below figures.



Please answer the following questions with explanation.

(1) What is the possible expression for the disappearance rates of species A? (4 points)

Continue question (1),

(2) Does the reaction follow Langmuir-Hinshelwood mechanism or Eley-Rideal mechanism? (3 points)

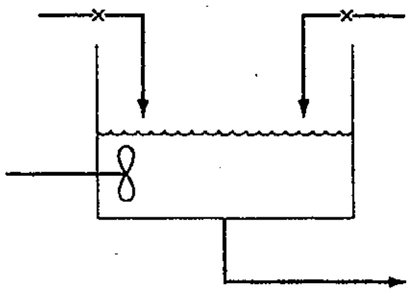
(3) Is there competitive adsorption on the catalyst surface? If so, which species compete each other? (3 points)

14. A liquid-phase reaction ($A \overset{k_1}{\rightarrow} B \overset{k_2}{\rightarrow} C$) is performed isothermally in a continuous-stirred tank reactor (CSTR). The reactor volume is 6 L. The concentration of species A entering reactor is 0.5 mol L^{-1}. The rate constants k_1 and k_2 are 0.4 and 0.1 min^{-1}, respectively. What is the entering volumetric flow rate that could lead to maximum concentration of species B at reactor outlet? (10 points)

15. The mixing tank shown here initially contains 50 kg of water at 25 °C. Suddenly the two inlet valves and the single outlet valve are opened, so that two water streams, each with a flow rate of 5 kg/min, flow into the tank, and a single exit stream with a flow rate of 10 kg/min leaves the tank. The temperature of one inlet stream is 80 °C, and that of the other is 50 °C. The tank is well mixed, so that the temperature of the outlet stream is always the same as the temperature of the water in the tank. (Assuming heat capacities $C_P = C_V$ for liquids.)

(1) Compute the steady-state temperature that will finally be obtained in the tank. (7 points)

(2) Develop an expression for the temperature of the fluid in the tank at any time. (8 points)



16. A clever chemical engineer has devised the thermally operated elevator shown below. The elevator compartment is made to rise by electrically heating the air contained in the piston-and-cylinder drive mechanism, and the elevator is lowered by opening a valve at the side of the cylinder, allowing the air in the cylinder to slowly escape. Once the elevator compartment is back to the lower level, a small pump forces out the air remaining in the cylinder and replaces it with air at 20 °C and a pressure just sufficient to support the elevator compartment. The cycle can then be repeated. There is no heat transfer between the piston, cylinder, and the gas; the weight of the piston, elevator, and elevator content is 4000 kg; the piston has a surface area

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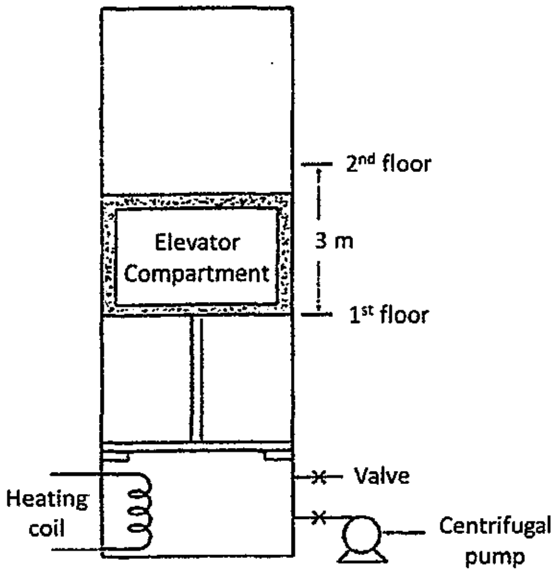
of 2.5 m^2; and the volume contained in the cylinder when the elevator is at its lowest level is 25 m^3. There is no friction between the piston and the cylinder, and the air in the cylinder is assumed to be an ideal gas with $C_P^* = 30$ J/(mol K)

How much heat must be added to the air during the process of raising the elevator 3 m, and what is the final temperature of the gas? (20 points)



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