

Problem 1 (26%)

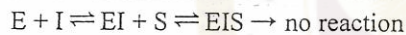
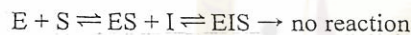
- (a) Consider a simple enzyme reaction $E + S \rightleftharpoons ES \rightarrow E + P$, where E, S, ES, and P stand for enzyme, substrate, enzyme-substrate complex, and product, respectively. Show that the rate equation for the simple enzyme reaction can be described by the Michaelis-Menten equation:

$$-r_s = \frac{r_{max} C_s}{K_M + C_s}, \text{ where the symbols remain their meanings defined in textbooks. (10\%)}$$

- (b) Estimate the Michaelis constant (K_M) and the maximum initial rate (r_{max}) for the following enzyme kinetic data. The units must be included with your answers. (8%)

Substrate concentration, C_s ($\mu\text{mol/L}$)	Initial reaction rate, $-r_s$ (nM/min)
3.7	20
13	60
39	126
79	174
230	232
400	244

- (c) The inhibitory mechanism for inhibitor I can be described with the following reactions.



Tell how the presence of inhibitor I affects K_M and r_{max} , and explain why. (8%)

Problem 2 (24%)

A substrate is converted to a product by the catalytic action of an enzyme, $E + S \rightleftharpoons ES \rightarrow E + P$, and the Michaelis-Menten kinetic parameters for this enzyme reaction are: $K_M = 0.03 \text{ mol/L}$ and $r_{max} = 13 \text{ mol/L min}$.

- (a) What should be the size of a steady-state CSTR to convert 95 percent of incoming substrate ($C_{S0} = 10 \text{ mol/L}$) with a flow rate of 10 L/hr ? (12%)
- (b) What should be the size of the reactor if you employ a PFR instead of the CSTR in part (a)? (12%)

Problem 3 (5%)

In the absence of any friction and other irreversibilities, can a heat engine have an efficiency of 100 percent?

Problem 4 (3%)

A substance whose Joule-Thomson coefficient is negative is throttled to a lower pressure. During this process, (select the correct statement)

- (a) the temperature of the substance will increase.
- (b) the temperature of the substance will decrease.
- (c) the entropy of the substance will remain constant.
- (d) the entropy of the substance will decrease.
- (e) the enthalpy of the substance will decrease.

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Problem 5 (5%)

What does it imply if the compressibility factor is larger than 1?

Problem 6 (12%)

Evaluate the following partial derivatives as functions of P , V , T , their partial derivatives and C_p

(a) $(\partial S / \partial P)_G$; (6%)

(b) $(\partial A / \partial G)_T$. (6%)

Problem 7 (25%)

A cylinder/piston contains air at ambient conditions, 101.3 kPa and 21°C with a volume of 0.283 m³. The air is compressed to 689.5 kPa in a reversible polytropic process with exponent, $n = 1.2$, after which it is expanded back to 101.3 kPa in a reversible adiabatic process.

(a) Show the two processes in P - v and T - s diagrams. (10%)

(b) Determine the final temperature and the net work. (10%)

(c) What is the potential refrigeration capacity of the air at the final state? (5%)