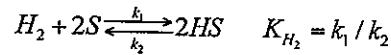


1. Consider a dissociative adsorption of hydrogen gas on a catalyst surface:



(a) Show that the surface coverage (θ) of the adsorption event can be described as the following equation. (6%)

$$\theta = \frac{\sqrt{P_{H_2} K_{H_2}}}{1 + \sqrt{P_{H_2} K_{H_2}}}$$

(b) Assume that the catalyst is used as a sensing element for H_2 gas sensor and the surface coverage at P_{H_2} can be estimated by the ratio of the sensing current at P_{H_2} to the saturated sensing current at a very high P_{H_2} (i.e., $q = I / I_{max}$). Describe how to determine K_{H_2} of the adsorption event with the H_2 sensor. The answer should include (i) a drawing of the experimental setup; (ii) a brief summary of experimental steps; (iii) a linear X-Y plot for K_{H_2} determination. (9%)

2. Consider isothermal, constant-volume reactors and answer the following questions:

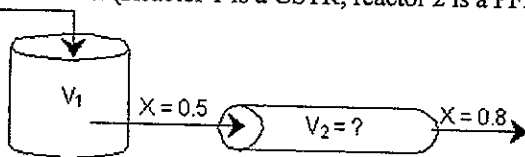
(a) The following reaction takes place in a CSTR: $A \rightarrow B$. Pure A is fed to the reactor under the following conditions: $F_{A0} = 10 \text{ mol/min}$, $C_{A0} = 2 \text{ mol/dm}^3$, $V = 500 \text{ dm}^3$ and $k = 0.1/\text{min}$. The rate law for the reaction is known as $-r_A = kC_A$. Determine the conversion X at the outlet of the CSTR. (7%)

(b) Consider a gas phase reaction carried out in two flow reactors in series (a CSTR + a PFR). The ratio of the molar flow rate to the reaction rate ($F_{A0}/-r_A$) can be correlated to the conversion by the following equations.

$$\frac{F_{A0}}{-r_A} = 100 + 800 \times X \text{ (dm}^3\text{)} \quad \text{for } 0 \leq X \leq 0.5$$

$$\frac{F_{A0}}{-r_A} = 500 - \frac{4000}{3} \times (X - 0.5) \text{ (dm}^3\text{)} \quad \text{for } 0.5 \leq X \leq 0.8$$

Use the graphical method to determine V_1 and V_2 for the following desired conversions. (Reactor 1 is a CSTR; reactor 2 is a PFR.) (8 %)



見背面

3. Consider the data of an enzyme that catalyzes the hydrolysis of methyl benzoate:

[Methyl Benzoate] (mmol/L)	Initial velocity, V_0 (nM/min)
3.7	20
13.0	60
39.0	126
79.0	174
230	232
400	244

- (a) Describe why enzyme kinetics should be assessed by an “initial” velocity rather than a “final” rate. (5%)
- (b) Please estimate the K_M and V_{max} values (including units) of the enzyme from the above data by “direct observation” and justify your answers. (5%)
- (c) If the enzyme reduces the activation energy for the hydrolysis reaction from $58 \text{ kJ}\cdot\text{mol}^{-1}$ to $10 \text{ kJ}\cdot\text{mol}^{-1}$. This corresponds to an acceleration of the reaction by a factor of 10^N at 300 K. $N=?$ (Note: Set $\log e = 0.43$ and $R = 8 \text{ J/mol}\cdot\text{K}$ for quick calculation.) (5%)
- (d) If one develops a new “better” enzyme using the recombinant DNA technology, how do you anticipate the changes in K_M and V_{max} for the new enzyme as compared to those you answered in (b). (5%)

4. Define the following terms: (a) dew-point temperature, (5%) (b) isothermal compressibility, (5%) (c) ideal Otto cycle. (5%)

5. If we consider the gravitational force, the change in Gibbs energy is expressed as $dG = VdP - SdT + mgdz$

(a) Derive the hydrostatic pressure distribution under the condition of equilibrium at constant temperature. (5%) What will this hydrostatic pressure distribution be for ideal gas? (5%)

(b) If the pressure in an oil reservoir decreases to low values, oil flow to the well practically stops. By injecting high-pressure carbon dioxide into the reservoir, the oil that is left in the reservoir can be recovered. Suppose that carbon dioxide is injected into a well 4.1 km deep at a pressure of 1.2×10^7 Pascal. If the temperature within the well is uniform and is at 20 °C, estimate the pressure at the bottom of the well. (5%)

6. For steady-state flow through a throttling valve with negligible changes in kinetic and potential energies, the first law states that the enthalpy remains constant, i.e. isenthalpic process. The variation of temperature with pressure in such a process is known as the *Joule-Thomson coefficient*, μ .

(a) Derive the Joule-Thomson coefficient in terms of temperature T , molar volume \tilde{V} and heat capacity. Recall that $\mu = \left(\frac{\partial T}{\partial P} \right)_H$ (7%)

(b) The throttling process may lead to an increase or decrease in temperature depending on the value of μ , i.e.

$$\mu \begin{cases} > 0, \text{ temperature decreases on throttling,} \\ < 0, \text{ temperature increases on throttling,} \end{cases}$$

The temperature at which the Joule-Thomson coefficient changes sign is called an *inversion temperature*. Show that the inversion condition, $\mu = 0$, is given by the equation (7%)

$$T \left(\frac{\partial P}{\partial T} \right)_{\tilde{V}} + \tilde{V} \left(\frac{\partial P}{\partial \tilde{V}} \right)_T = 0.$$

(c) Consider a gas obeying an equation of state of the form $P = \frac{RT}{\tilde{V} - b} - \frac{a}{\tilde{V}^2}$.

Determine the inversion temperature and state your assumption. (6%)