

# 國立中正大學八十四學年度碩士班考試試題

所 別：化學工程研究所

科 目：化工熱力學與化工動力學

## Thermodynamics

1. Calculate the theoretical flame temperature (i.e., the maximum attainable temperature) for the following cases:
- when  $H_2$  at  $37^\circ C$  is burned with the theoretical amount of  $O_2$  at  $25^\circ C$ ;
  - when  $H_2$  at  $37^\circ C$  is burned with the theoretical amount of air at  $25^\circ C$ ; assuming complete combustion and  $N_2$  as a nonreactive gas, given



and

$$C_p = a + bT + c T^{-2} \quad \text{cal/g-mole } ^\circ C$$

with

(12%)

substance	a	$b \times 10^3$	$c \times 10^{-5}$
$H_2O_{(g)}$	7.3	2.46	0
$H_2$	6.52	0.78	0.12
$O_2$	7.16	1.06	-0.4
$N_2$	6.83	0.9	0

2. Two identical bodies have equations of state  $U = N C_V T$ , with  $C_V$  a constant and  $N$  and  $C_V$  of the same values for each system. The initial temperature are  $T_1$  and  $T_2$ , and they are to be used as a source of work by bringing them to a common temperature  $T_f$ . (9%)
- What is the range of possible final temperatures?
  - What is the final temperature for a reversible process?
  - What is the maximum amount of delivered work, i.e.,  $W_{rev}$ ?
3. Find the relation between the number of degrees of freedom  $F$ , the number of independent components  $c_{ind}$ , and the number of phases  $p$  for each of the following systems: (8%)
- rigid, permeable, adiabatic walls separate all the phases of a system.
  - movable, permeable, adiabatic walls separate all the phases of a system.
  - movable, impermeable, thermal conducting walls separate all the phases of a system.
  - movable, permeable, thermal conducting walls separate all the phases of a system.
4. In the study of an engine, one cycle consists of at least the following three steps:
- An adiabatic compression from  $P_1, T_1, V_1$ , to  $P_2, T_2, V_2$ .
  - A constant-volume path from  $P_2, T_2, V_2$ , to  $P_3, T_3, V_2$  with an input of heat  $\Delta H$ .
  - An adiabatic expansion from  $P_3, T_3, V_2$ , to  $P_4, T_4, V_1$ .
- Sketch these steps on a PV diagram, and calculate  $T_2, P_2, T_3, P_3, T_4, P_4$ , and  $W$  for each of the steps in terms of  $T_1, V_1, V_2, \Delta H$ , and  $\gamma$  (i.e.,  $C_p/C_V$ ). Assume reversible operation, and take the working substance to be an ideal gas with constant heat capacities. (14%)
5. For binary liquid solutions of components which have comparable molecular volumes, it is observed that the excess Gibbs free energy at constant  $T$  and  $P$  is represented by

$$\frac{G^E}{RT} = A x_1 x_2$$

where  $A$  is independent of  $x$ , and the standard states are the states of pure components at  $T$  and  $P$ . Develop expressions for  $\ln \gamma_1$  and  $\ln \gamma_2$  as functions of composition, where  $\gamma$  is activity coefficient. (7%)

Hint:

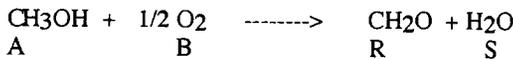
$$\ln \gamma_1 = \frac{\bar{G}_1^E}{RT}$$

**Kinetics**

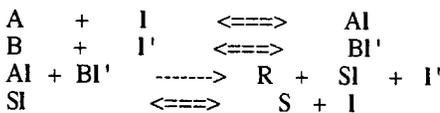
6. The hydrolysis of urea is catalyzed by the enzyme urease. A rate equation,  $r=k C_u/(K+ C_u)$ , is expected to be suitable for describing the reaction kinetics. From the following data, evaluate the parameters, K and k, of the rate equation. (15%)

concentration of urea, $C_u$ (mol/L)	initial reaction rate (mol/(L·s))
0.00015	0.060
0.00032	0.130
0.00065	0.226
0.00129	0.362
0.00327	0.600
0.00830	0.846
0.01670	0.975
0.03330	1.030

7. It is proposed for the catalytic oxidation of methanol to formaldehyde



that the reaction over a ferromolybdenum catalyst proceeds by the following scheme utilizing two type of sites, I and I':



For irreversible surface reaction (step 3) rate controlling, develop a rate expression for the reaction. (20%)

8. A gas phase reaction,  $\text{A} \text{----}> 2\text{R}$ , is carried out in a tubular plug flow reactor at  $T = 60^\circ\text{C}$  and  $P_t = 4.75 \text{ atm}$ . The feed consists of 50 mole % A and 50 mole % inert at a rate of 4000 Kg/hr. The molecular weights of A and inert are 40 and 20, respectively, and the rate coefficient is  $k = 2000 \text{ hr}^{-1}$ . Determine the reactor size for 35% conversion of A by assuming the reaction to be first order. (15%)