國立雲林科技大學
九十一學年度研究所碩士班入學考試試題

系所：化工所
科目：化工熱力學

1. Evaluate the following difference for the ideal gas, van der Waals gas, and for a gas that obeys the virial equation of state. (15%)

$$\left(\frac{\partial \underline{U}}{\partial T}\right)_P - \left(\frac{\partial \underline{U}}{\partial T}\right)_V$$

2. Please derive the equilibrium and stability criteria for the following system:
   (a) isothermal closed system with fixed boundaries; (5%)
   (b) isothermal, isobaric open system moving with the fluid velocity. (10%)
3. If the excess Gibbs free energy for a binary system can be expressed as the following equation

$$G^E / RT = \beta x_1 x_2$$

where β is independent of x.
   (a) If the standard states considered are based on the Lewis-Randall rule for both components, what is the activity based on the above excess Gibbs free energy? (10%)
   (b) If the standard states considered are based on the Henry's law for both components, what is the excess Gibbs free energy? (10%)
4. An ideal gas($C_P = 3.5R$ and $C_V = 2.5R$, where R = 8.314 J/mole-K) is at 303.15 K and 100 kPa initially. It is first compressed adiabatically to 500 kPa, then cooled at a constant pressure of 500 kPa to 303.15 K, and finally expanded isothermally to its original state. But each step is irreversible with an efficiently of 80% compared with the corresponding mechanical reversible process. Calculate Q(J/mole), W(J/mole), ΔU(J/mole), and ΔH(J/mole) for each step of the process. (20%)
5. An adiabatic steady-state steam turbine is being designed to serve as an energy source for a small electrical generator. The inlet to the turbine will be steam at 1000 °F and 10 atm (H=1530 Btu/lb) with a velocity of 250 ft/sec and a flow rate of 5 lb/sec. The conditions at the turbine exit are T=700 °F and P=1 atm (H=1381 Btu/lb) with a gas velocity of 100 ft/sec. If the inlet and outlet have the same level, estimate the rate at which work(Btu/sec) can be obtained from this turbine (1 Btu = 778.16 ft-lbf). (10%)
6. (a) What is corresponding state principle? (4%)
   (b) What is excess property? (4%)
   (c) What is isenthalpic process? (4%)
   (d) What is the Carnot cycle for an ideal gas? (4%)
   (e) An ideal gas expands isothermally. Does its entropy go up, down, or stay the same？ How about the enthalpy？ Explain. (4%)

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1. (20 %) The reaction rate of a homogeneous gas reaction, $A \longrightarrow 3R$, at 215 °C is $-r_A\,[\mathrm{mol/(dm^3)(s)}] = 0.01\,C_A^2$. Find the space-time needed for 60 % conversion of a 50 % A- 50 % inert feed to a well-mixed reactor operating at 215 °C and 5 atm. [R = gas constant = 0.082 $(\mathrm{dm^3})(\mathrm{atm})/(\mathrm{mol})(\mathrm{K})$]

2. (15 %) A catalytic reaction $R \longrightarrow P$ is carried out in a batch reactor. The experimental results exhibit the following behavior: (1)Reaction rate is proportional to the concentration of catalyst introduced into the mixture, $[C_o]$; (2)At very low reactant concentration the rate is proportional to the reactant concentration, [R]; (3)At very high reactant concentration the rate levels off and becomes independent of reactant concentration. Propose a mechanism to account for this behavior.

3. (15 %) A human being (60 kg) consumes about 4800 kJ per day. Assume that the energy needed is supplied by the oxidation of glucose $(C_6H_{12}O_6)$ with O_2, and CO_2 and H_2O are the products. Find the rate of reaction in terms of moles of oxygen used per m^3 of person per second. (Data: density of man is 1000 kg/m^3; heat of reaction, $-\Delta H_r = 2816$ kJ/mole glucose; atomic weight: H, 1.0; C, 12.0; O, 16.0)

4. （15 分）

Calculate the time needed to completely burn graphite particles in an 8 % oxygen stream (volume%) at 900°C and 1 atm. Assume that film diffusion does not offer any resistance and the surface reaction is occurring as Equation (4):

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad (4)$$

Data for graphite particle: initial radius = 5 mm, density = 2.2 g/cm^3, atomic weight of carbon = 12 g/gmol, and the surface reaction rate constant = 20 cm/s.

5. （20 分）

A reaction proceeds adiabatically in a CSTR of 50 Liter (L). The rate equation is

$$r_a = C_a^{1.5} \exp\left(14 - \frac{5000}{T}\right) \qquad (5)$$

where the units of r_a are mol/L-hr. The flow rate is 25 L/hr or 100 mol/hr of which 30% is reactant A. The inlet temperature is 350 K, heat capacity is 6 cal/mol-K, and the enthalpy change of reaction is ΔHr = –2000 cal/gmol of A reacted. You may assume no volume change during reaction.

(a) Assuming the outlet temperature at 376.6 K, calculate the molar flow rate (mol/hr) of unreacted A out of the reactor, and the reaction rate constant.

(b) Show that an outlet temperature of 376.6 K is a valid solution.

6. （15 分）

The method of chemical vapor deposition is used to grow stable thin film of polycrystalline silicon (Si) and other materials for use in microelectronics industry. One type of process is developed to proceed by the irreversible two-step mechanism in Equations (6a) and (6b):

$$SiH_4 + S \xrightarrow{k1} SiH_2 \cdot S + H_2 \qquad (6a)$$

$$SiH_2 \cdot S \xrightarrow{k2} Si + H_2 + S \qquad (6b)$$

In this mechanism, the irreversibly adsorbed SiH$_2$ (e.g., $SiH_2 \cdot S$) reacts as fast as it is formed, so that it can be assumed to behave as an active intermediate.

(a) Identify the rate-limiting step, and derive a rate law using the pseudo-steady -state hypothesis (PSSH). (10%)

(b) Determine if this mechanism is consistent with the following data: (5%)

Deposition Rate (mm/min)	0.1	0.25	0.5	0.7	0.77	0.8	0.82
Silane Pressure (mtorr)	2	5	15	25	40	60	75

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1. A Newtonian fluid of viscosity (μ) and density (ρ) flows steadily as a uniform film with thickness L down a wide inclined plane. (see, Fig. 1)

   (a) Derive the velocity profile within the film. (10%)

   (b) If $\theta = 30°$ and the mass rate of water flow ($\rho = 1000\ \text{kg/m}^3$; $\mu = 1$ cp) per unit width of plane is 0.12 $\text{kg/s}\cdot\text{m}$, calculate the film thickness. (10%)

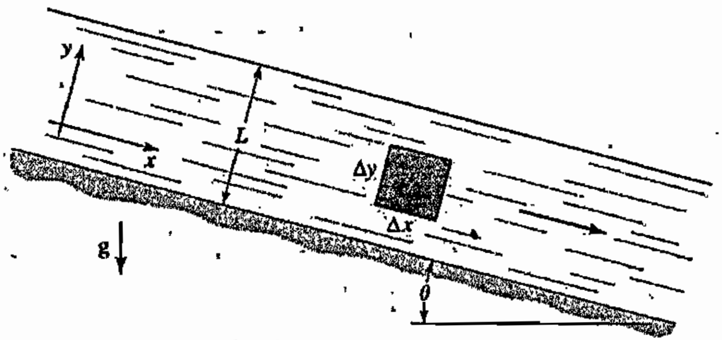

Fig. 1

2. Consider a viscous flow of a fluid with constant kinematic viscosity ν near a wall suddenly set in motion. Initially, the fluid and wall are at rest. At time $t \geq 0$ the wall is set in motion in the positive x-direction with a velocity v_∞. There is no pressure gradient or gravity force in the x-direction, the flow is assumed to be laminar.

   (a) Using variables $\phi(\eta) = v_x / v_\infty$ and $\eta = y/\sqrt{4\nu t}$, derive the (transformed) ordinary differential equation and its boundary conditions. (10%)

   (b) Derive the velocity profile. (Hint: $erf(\eta) = \frac{2}{\sqrt{\pi}} \int_0^\eta e^{-\mu^2} d\mu$ and $erf(\infty) = 1$) (10%)

3. The extended surface (fin), which the fin surface area is A_s and the fin perimeter is P, is attached to a base surface of temperature T_b at a surrounding temperature T_∞. Both thermal conductivity k and heat transfer coefficient h are assumed to be constant.

   (a) If the cross section area A_c varies with x-direction, derive the differential equation. (10%)

   (b) If the fin is very long and the cross section area A_c becomes uniform, derive temperature distribution. (10%)

4. Considering a fluid flow in the circular tube of which the tube wall is heated by a constant heat flux, q. If the velocity profile is parabolic form, i.e., $V_z = V_{max}[1-(r/R)^2]$, where R is the radius of the tube, please show that this system has a Nusselt number (Nu) of 48/11. (15%)

5. Consider a thin static film of material that separates two gaseous regions of different concentrations. Suppose the concentrations of species A are denoted by partial pressures $P_{A,0}$ and $P_{A,L}$ in the gas on each side of the film. We suppose that the two interfaces at z = 0 and z = L are in equilibrium, with the result that the concentrations within the film, at the interface, satisfy a relationship such as Henry's law

$$C_A = H \cdot P_A$$

with H constant. In addition, there is chemical reaction within the film material during species A passing through the film. The chemical reaction complies with kinetics of first-order. Please set up a differential equation and boundary conditions to obtain the concentration profile and flux of species A across the film, if the system is steady state and $P_{A,L} = 0$. (15%)

6. A continuous countercurrent dryer is being used to dry 453.6 kg dry solid/h containing 0.04 kg total moisture/kg dry solid to a value of 0.002 kg total moisture/kg dry solid. The granular solid enters at 26.7℃ and is to be discharged at 62.8℃. The dry solid has a heat capacity of 1.465 kJ/kg·K, which is assumed constant. Heating air enters at 93.3℃, having a humidity of 0.01 kg H_2O/kg dry air, and is to leave at 37.8℃. Calculate the air flow rate and the outlet humidity, assuming no heat losses in the dryer. (notation: the latent heat, λ_0, of water at 0℃ is 2501 kJ/kg, the heat capacity, C_{pA}, of liquid moisture is 4.187 kJ/kg H_2O·K, and the humid heat, C_S, is $(1.005 + 1.88H)$ in kJ/kg dry air·K) (10%)