國立成功大學104學年度碩士班招生考試試題

系所組別：化學工程學系甲組

考試科目：化工熱力學

考試日期：0211，節次：2

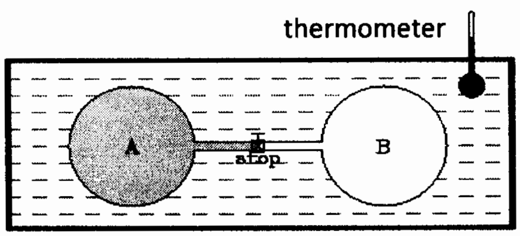
※ 考生請注意：本試題可使用計算機。 請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. **(12%)** Answer False (F) or True (T). For those "false", You **MUST** give your explanation.

   (a) (4%) Turbine needs work. Therefore, the operation of an turbine could cause the increasing of enthalphy from the receiving of work.

   (b) (4%) For an ideal gas, C_P and C_V are constant.

   (c) (4%) For the gas full of a vessel (A) to expand into an equal-volume (V) evacuated vessel (B), the pressure in A and B are denoted as P_A and P_B, respectively: It has two recesses with a dividing valve. Once the valve is fully opened, gas escapes from the left side to fill the whole space. Taking the gas in A as the system, thus, the gas gives up work in the amount of $P_A \cdot V$.



2. **(22%)** A mass of 200 g of *n*-butane is contained in a 10,000 cm^3 vessel immersed in a constant-temperature bath of 70°C. Please calculate the pressure of the gas by the generalized second virial-coefficient correlation. The equations and parameters you may need are listed as below.

   (a) Please calculate the pressure by the ideal-gas equation. **(4%)**

   (b) Proceed **THREE** iterations to get the answer for the pressure with the initial guess of 5 bar. **[Note]** You **MUST** list the answer of each iteration. **(18%)**

Where Z is the compressibility factor; B is the second virial coefficient of the virial equation of state; P_r and T_r are the reduced pressure and temperature, respectively. ω is the acentric factor; T_c and P_c are the temperature and pressure at the critical point, respectively; B^0, B^1, Z^0, Z^1 and $\hat{B}$ are the coefficients for this correlation.

$$Z = 1 + \frac{BP}{RT} = 1 + \hat{B} \cdot \frac{P_r}{T_r} \qquad \hat{B} = \frac{BP_c}{RT_c} = B^o + \omega B^1 \qquad B^o = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$Z = 1 + B^o \frac{P_r}{T_r} + \omega B^1 \frac{P_r}{T_r} \qquad Z^o = 1 + B^o \frac{P_r}{T_r} \qquad Z^1 = B^1 \frac{P_r}{T_r} \qquad B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$\omega = 0.200 \qquad T_c = 425.1\,K \qquad P_c = 37.96\ bar$$

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3. **(15%)** Let us consider a real gas, whose constant-pressure heat capacity C_p is as same as that of an ideal gas. Moreover, its enthalpy could be generally expressed as a function of temperature T and pressure P.

(a) Please devise a scheme to estimate the residual enthalpy H^R of this gas as a function of T and/or P. **(5%)**

(b) If the PVT behavior of this gas can be described by the Soave-Redlich-Kwong (SRK) Equation of State as $P = \dfrac{RT}{V-b} - \dfrac{a}{V(V+b)}$, where the parameter b is a constant but the parameter a is a function of temperature T and the acentric factor ω, please calculate explicitly the residual enthalpy H^R of this gas. **(10%)**

4. **(18%)** A gas-turbine engine is schematically shown as **Figure 1**. If the working medium is an ideal-gas-like air with a constant heat capacity and heat exchangers are provided in replacing the combustion chamber to heat the air and in connecting the exit of the turbine (Point D) and the inlet of the compressor (Point A), this thermodynamic cycle is called the air-standard gas-turbine cycle, *aka* the air-standard Brayton cycle. Generally speaking, in an air-standard gas turbine engine, air is *adiabatically* compressed in the compressor from P_A at Point A to P_B at Point B, heated up *isobarically* from Point B to Point C, and subsequently *isentroprically* expanded from Point C to Point D to produce work. The pressure at Point D is often taken as the same as that at Point A.

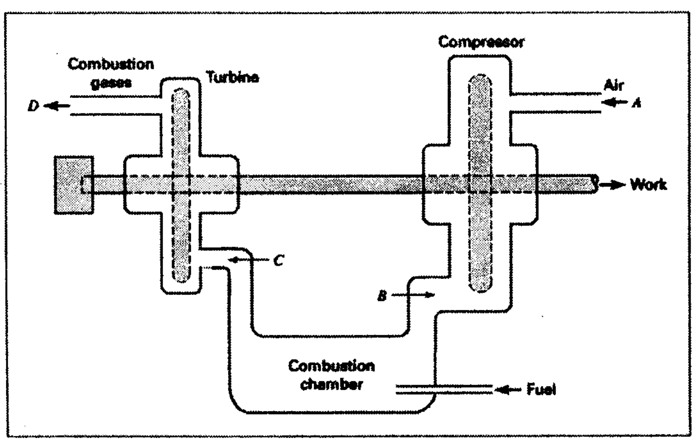

Figure 1: Gas-turbine engine

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There is an air-standard gas-turbine cycle modified by installation of a regenerative heat exchanger to transfer energy from the air leaving the turbine to the air leaving the compressor. In an optimum countercurrent exchanger, the temperature of the air leaving the compressor is raised to that of Point D in Figure 1 (the exit of the turbine), and the temperature of the gas leaving the turbine is cooled down to that at Point B in Figure 1 (the exit of the compressor).

(a) Please sketch this modified Brayton cycle on a *PV* diagram. **(3%)**

(b) What is the thermal efficiency of this modified Brayton cycle? **(15%)**

5. **(22%)** For a binary liquid system of species 1 and 2 at fixed *T* and *P*, the partial molar enthalpy of species 1 can be expressed as $420 - 60\, x_1^2 + 40\, x_1^3$ and the partial molar enthalpy of species 2 can be expressed as $600 + 40\, x_1^3$, where x_1 is the mole fraction of species 1.

(a) Explain the physical meaning of partial molar property of a species in solution and determine the expression for the enthalpy of the binary liquid system as a function of x_1. **(8%)**

(b) Show that the expressions for the partial molar enthalpies of species 1 and 2 satisfy the Gibbs/Duhem equation. **(6%)**

(c) Explain the physical meaning of excess property and determine the expression for the excess enthalpy of the binary liquid system as a function of x_1. **(8%)**

6. **(11%)** Explain the physical meanings of the fugacity coefficient and activity coefficient of a species in solution and describe how to evaluate activity coefficients from experimental low-pressure vapor/liquid equilibrium data.