國立臺灣科技大學
九十二學年度碩士班招生考試試題
系所組別：化學工程系碩士班
科　目：化工熱力學與動力學

總分100分

Part I. 化工熱力學 (50 %)

1. Figure 1 is a refrigeration system, which is operated under the following assumptions:
   - Refrigerant leaving the condenser is a saturated liquid.
   - Refrigerant entering the evaporator is a saturated vapor.
   - The temperature difference between the condensing refrigerant and the exhausted air is 5°C, and that between the cooled air and the evaporating refrigerant is also 5°C.
   - The pressure drops in the heat-changers are neglected.
   - The compression process is adiabatic and reversible.

   HFC-134a is used as the working fluid and its P-H diagram is given in Figure 2. Please answer the following questions:

   (a) What is the condensing pressure?
   (b) What is the evaporating pressure?
   (c) What is the enthalpy (kJ/kg) of the inlet stream to the evaporator?
   (d) What is the energy requirement to compress 1 kg of refrigerant?
   (e) What is the temperature of the outlet stream from the compressor?

(20 %)

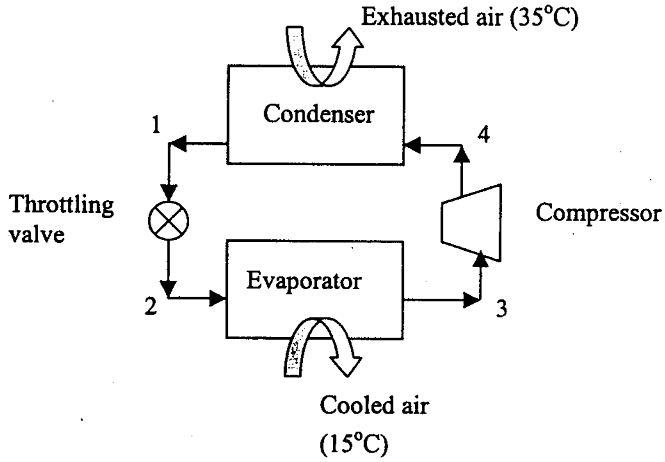

Figure 1 A refrigeration system

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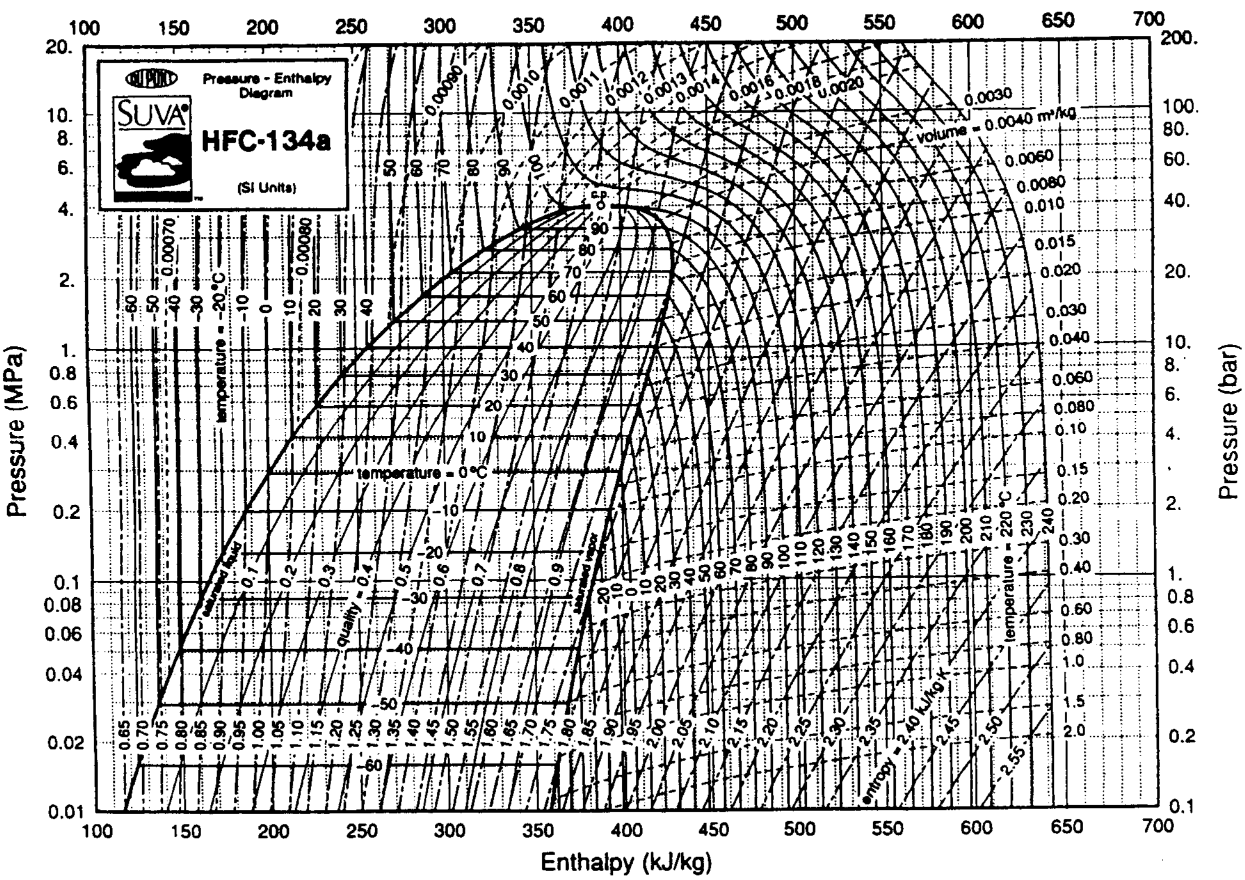

Figure 2 P-H diagram of HFC-134a

2. There are two cylinders in your laboratory, in which the room temperature was controlled at 25°C. One cylinder stores pure nitrogen and the other contains pure carbon dioxide. The pressure gauges indicate that the initial pressure is 200 bar in the nitrogen cylinder and 56 bar in the carbon dioxide cylinder. Compare the pressure variations between these two cylinders during the discharging process, if each chemical is released from the cylinder to ambient at a constant flow rate. Assume that the gas phase behaves as an ideal gas. Please qualitatively plot the curves of pressure (in the cylinder) against time, from t = 0 up to almost empty. Give briefly explanation to support your answers. The thermodynamic properties of these two chemicals are as following:

Nitrogen: critical pressure = 33.9 bar, critical temperature = 126.2 K, critical volume = 89.8 cm^3/mol, acentric factor = 0.039.

Carbon dioxide: critical pressure = 73.8 bar, critical temperature = 304.1 K, critical volume = 93.9 cm^3/mol, acentric factor = 0.239

(15%)

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3. A binary system contains water and nitrogen at vapor-liquid equilibrium (VLE). This equilibrium system is at 25°C and 1 bar. The vapor phase can be assumed as an ideal gas mixture and the solubility of nitrogen in the liquid phase is very small. Please calculate
   (a) the mole fraction of water in the vapor phase, and
   (b) the solubility of nitrogen in the liquid phase,

   based on the criteria of VLE. Briefly explain your derivation to make the calculation.

   Supporting information:
   The vapor pressure of water is about 0.03169 bar at 25°C
   The Henry's constant of nitrogen dissolved in water is about 5×10^4 bar at 25°C and 1 bar.

(15%)

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Part II. 化工動力學 (50 %)

4. (30%) For the irreversible gas-phase reaction:

   $A(g) \rightarrow 2B(g)$

   The following rate information were determined from laboratory data with initial concentration of A equals to 0.4 mol dm^{-3} and volumetric flow rate of 10 $dm^3\,s^{-1}$

   For $x \le 0.5$: $-r_A^{-1} = 2.5 \cdot 10^2\ dm^3\,s\,mol^{-1}$

   For $x > 0.5$: $-r_A^{-1} = [2.5 + 10(x - 0.5)] \cdot 10^2\ dm^3\,s\,mol^{-1}$

   a) What conversion will be achieved in a CSTR that has a volume of 450 dm^3?
   b) What plug-flow reactor volume is needed to achieve 80% conversion?
   c) What CSTR reactor volume is needed if the effluent from the PFR in part b) is fed to a CSTR to raise the conversion to 90%?

5. (10%) Chemicals emitted to the atmosphere undergo oxidation through a wide range of processes. One of the critical steps in these oxidations is the rate of reaction with the hydroxyl radical (OH·). The relative rate at which a hydroxyl radical reacts with a compound is a semi-quantitative indicator of how long the compound will persist in the atmosphere. For example, the reaction rate of the elementary reaction in which hydroxyl radical reacts with propene is 2.6 x 10^{-11} cm^3/molecule-sec.

   $$CH_3CHCH_2 + OH\cdot \rightarrow CH_3\text{-}CH\text{-}CH_2OH\cdot$$

   The concentration of propene is assumed to be at steady state, with a typical value of 1.5 x 10^6 molecules/cm^3. Please estimate the atmospheric half-life of propene.

6. (10%)To remove NO from automobile exhaust, it has been proposed to use unburned CO in the exhaust to reduce NO over a solid catalyst according to the reaction:

   $$CO + NO \rightarrow 0.5\,N_2 + CO_2$$

   Experimental data indicate that the reaction can be represented over a large temperature range by

   $$-r_{NO} = kP_{NO}P_{CO}(1 + K_1P_{NO} + K_2P_{CO})^{-2}$$

   where P_{NO} is the gas-phase partial pressure of NO, and P_{CO} is the gas-phase partial pressure of CO. Please propose an adsorption-surface reaction-desorption mechanism that will explain the experimentally derived reaction kinetics.