國立清華大學 108 學年度碩士班考試入學試題
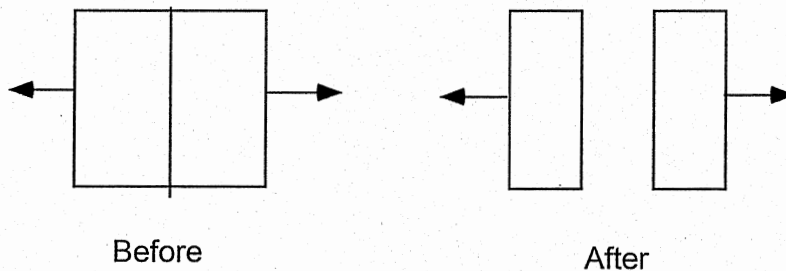
系所班組別：工程與系統科學系 甲組
考試科目(代碼)：材料熱力學(3002)

一作答注意事項一

1. Entropy is a state function defined in the Second Law of Thermodynamics. Entropy has classical and statistical aspects. (a) Write down the equation that defines the entropy in classical thermodynamics. You should give the definition of every term in the equation.(4%) (b) The statistical thermodynamics gives the physical meaning of entropy, in which both energy and configuration are related to entropy. Give the statistical meaning of entropy related to energy and configuration.(4%) (c) From statistical thermodynamic viewpoint, information contains entropy. Try to use the Boltzmann equation to compare the entropy contents in the following news. Please answer which one contains higher entropy and state your analysis approach. (1)State-run oil refiner CPC Corp, Taiwan yesterday announced that it would lower gasoline and diesel prices by NT$0.1 per liter, effective today. The price cuts reflect last week's weakness in international crude oil prices, due to concerns over higher US crude production and the weak market outlook for next year, CPC said in a statement, adding that the average cost of its crude oil per barrel last week fell from US$60.19 to US$59.39.(2)The movement of oil prices in Taiwan in the short term depends on the development of global trade issues, but in the long run, oil prices are expected to rise as major oil-producing countries may agree on production cuts, CPC vice president Fang Jeng-zen told the Central News Agency yesterday.(8%) (d) Is the statement that entropy always increases in an irreversible process true or false? Discuss your answer according to the Second Law of Thermodynamics.(4%)

2. The work performed in creating surfaces can be added to the work flows in the First Law of Thermodynamics. If γ is defined as the surface energy per unit area, the work performed when creating new surface is γdA, where A is the surface area of the system. The cleavage surface of silicon (Si) is (110) that has a surface energy (solid-gas) which over the temperature range of interest increases with temperature as $B + C \ln(T)$ with C and B positive constants. A single crystal of Si is reversibly pulled apart along (110) plane as shown in the figure below. The crystal is insulated so that there is no heat flow to the environment.
   (a) Calculate the change in entropy of the system (per unit new surface area) as the crystal is isothermally and reversibly pulled apart. Answer can be in terms of constants B,C, and T (temperature). (10%)
   (b) What happens to the temperature of the system if the crystal is pulled apart adiabatically (but reversibly). (10%)
   Assume that there is no plastic deformation in the system while it is being pulled apart.

Before   After

3.(20%) Two compartments, each containing chemical species A, B and C in different concentrations, are in contact through a semi-permeable diaphragm. The semi-permeable diaphragm does not allow for permeation of A, B or C individually, but only allows a pair of molecules A-B to pass through together. The whole system is at constant temperature and pressure. Derive the equilibrium conditions imposed on the chemical potentials for this system.
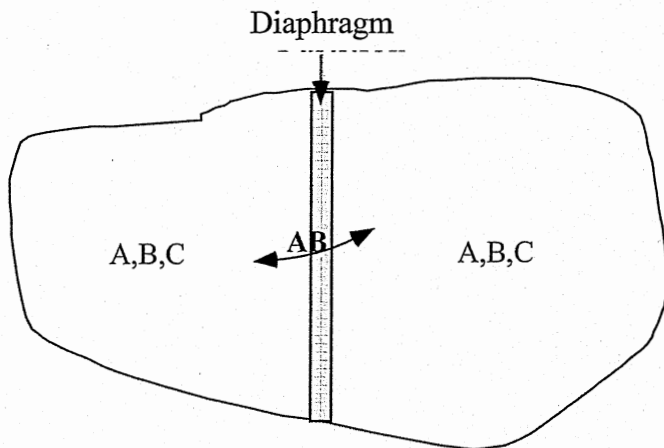
4. If the specific Helmholtz free energy f for a van der Waal gas is given as

$$f = f_o + C_v(T - T_o) - TC_v \ln T / T_o - a\left(\frac{1}{v} - \frac{1}{v_o}\right) - RT \ln\left(\frac{v-b}{v_o - b}\right) - s_o(T - T_o),$$

Where T_o is the temperature of the gas at some arbitrary reference state with specific volume, entropy and free energy v_o, s_o, and f_o, respectively, and a and b are constants of the van der Waal gas, derive (a) the equation of state (10%), and (b) the equation of internal energy (10%).

5. (20%) Plasma etching is a key process in semiconductor industry. An IC plasma etcher has a vacuum chamber made by aluminum alloy. In the etching process, chlorine (Cl_2) gas is passed through the chamber. It is known that chlorine gas is highly corrosive, and thus the inner wall of the chamber was coated with an aluminum oxide layer to protect the chamber. If you are a design engineer, you may concern the temperature at which Al_2O_3 will react with Cl_2. Supposed that the temperature of the inner wall is 300°C, use the following reactions as well as the free energies of formation, to estimate the possibility that the chamber may be corrode by Cl_2.

Given

$2Al(s) + Cl_2(g) = 2AlCl(g)$ $\Delta G(cal) = -21360 + 11.75T\log_{10}T - 76.5T$

$2Al(s) + 3Cl_2(g) = 2AlCl_3(g)$ $\Delta G(cal) = -276320 + 4.96T\log_{10}T + 9.50T$

$2Al(s) + 3Cl_2(g) = Al_2Cl_6(g)$ $\Delta G(cal) = -304440 + 4.95T\log_{10}T + 4.23T$

$Al_2O_3(s) = 2Al(s) + 1.5O_2(g)$ $\Delta G(cal) = 400810 + 3.98T\log T_{10} - 87.64T$