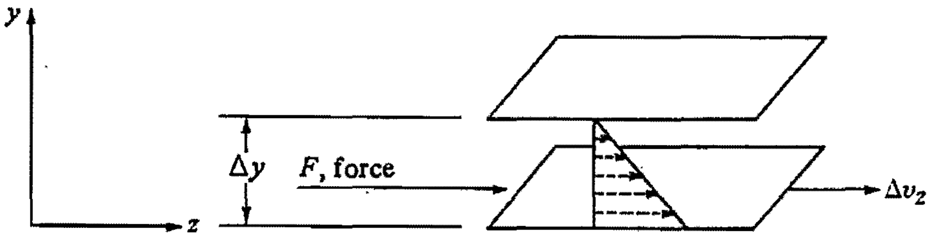
1. Whole milk at 293 K having a density of 1030 kg/m^3 and viscosity of 2.12 cp is flowing at the rate of 0.605 kg/s in a glass pipe having a diameter of 63.5 mm.
   (a) Calculate the Reynolds number. Is this turbulent flow? (10%)
   (b) Calculate the flow rate needed in m^3/s for a Reynolds number of 2100 and velocity in m/s. (10%)

2. Using the below figure, the lower plate is being pulled at a relative velocity of 0.40 m/s greater than the top plate. The fluid used is water at 24°C (viscosity of 0.9142×10^{-3} Pa • s).
   (a) How far apart should the two plates be placed so that the shear stress τ is 0.30 N/m^2? Also, calculate the shear rate. (10%)
   (b) If oil with a viscosity of 2.0×10^{-2} Pa • s is used instead at the same plate spacing and velocity as in part (a), what are the shear stress and the shear rate? (10%)



3. A fluid flowing in laminar flow in the x direction between two parallel plates has a velocity profile given by the following

$$v_x = v_{x\,\max}\left[1 - \left(\frac{y}{y_0}\right)^2\right]$$

where $2y_0$ is the distance between the plates, y is the distance from the center line, and v_x is the velocity in the x direction at position y. Derive an equation relating $v_{x\,av}$ (bulk or average velocity) to $v_{x\,\max}$. (10%)

4. Consider a steam pipe of length $L = 30$ m, inner radius $r_1 = 6$ cm, outer radius $r_2 = 10$ cm, and thermal conductivity $k = 20$ W/m.℃. The inner and outer surfaces of the pipe are maintained at average temperatures of $T_1 = 180$℃ and $T_2 = 60$℃, respectively. (12% all)

(a). Assume: one-dimensional heat conduction in the r direction only, i.e. $T = T(r)$, steady-state, and there is no heat generation. The heat equation can be can be derived as:

$$\frac{d}{dr}\left(r\frac{dT}{dr}\right) = 0$$

Together with the following boundary conditions:

$$T(r_1) = T_1 \quad \text{and} \quad T(r_2) = T_2$$

Derive that the temperature distribution inside the pipe is:

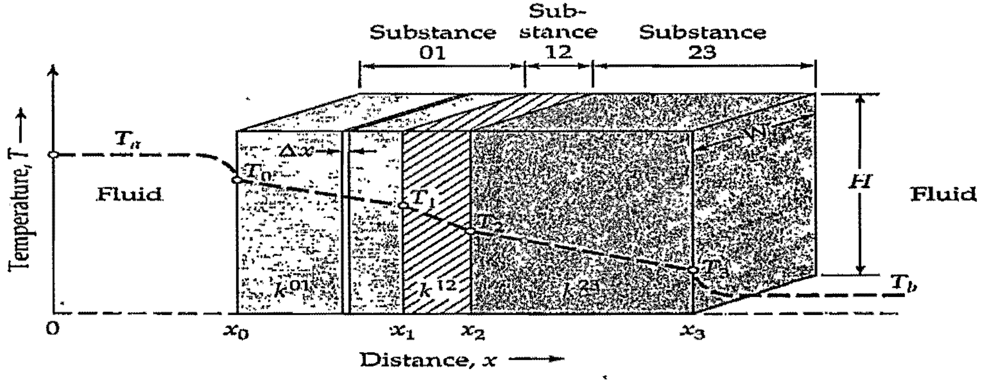
$$T(r) = \frac{(T_2 - T_1)}{\ln(r_2/r_1)}\ln(r/r_1) + T_1 .$$ 4%

(b). ***Calculate*** the heat flux at $r = 8$ cm. 4%

(c). ***Calculate*** the rate of heat conduction through the pipe. 4%

5. ***Heat conduction through composite walls*** (14% all)

(a). As shown in the following figure, a composite wall is made up of three materials of different thicknesses, $x_1 - x_0$, $x_2 - x_1$, and $x_3 - x_2$, and different conductivities k_{01}, k_{12}, and k_{23}. At $x = x_0$, substance 01 is in contact with a fluid at temperature T_a, and at $x = x_3$, substance 23 is in contact with a fluid at temperature T_b. The convective heat transfer coefficients at the boundaries $x = x_0$ and $x = x_3$ are h_0 and h_3, respectively.



BIRD: *Transport Phenomena, 2e*
Fig. 10.6-1 W-150

Assume: one-dimensional heat conduction in the x direction only, i.e. $T = T(x)$, steady-state, and there is no heat generation. ***Derive that*** the heat flux can be calculated by:

$$q_0 = U(T_a - T_b)$$

where U, called the "overall heat transfer coefficient," is given by:

$$\frac{1}{U} = \frac{1}{h_0} + \frac{x_1 - x_0}{k_{01}} + \frac{x_2 - x_1}{k_{12}} + \frac{x_3 - x_2}{k_{23}} + \frac{1}{h_3}$$ <u>5%</u>

Hint:

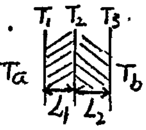
The energy balance equation $\frac{d}{dx} q_x = 0$ and the Fourier's law $q_x = -k\frac{dT}{dx}$.

(b). Now, consider only two layers. A composite wall is made up of two materials of different thicknesses, $L_1 = 0.004$ m and $L_2 = 0.01$ m, different conductivities $k_1 = 0.78$ W/m.℃ and $k_2 = 0.026$ W/m.℃, and same surface areas $A = 1.2$ m^2. The temperatures of the two fluid streams are $T_a = 30$℃ and $T_b = 0$℃. The convective heat transfer coefficients at the boundaries are $h_a = 10$ W/m^2.℃ and $h_b = 40$ W/m^2.℃. ***Calculate***:

(i). The overall heat transfer coefficient U and the heat flux q_0. <u>4%</u>

(ii). The temperatures at the boundaries of the two materials T_1, T_2, and T_3. <u>5%</u>

<u>Note</u>: The temperatures are in the order of $T_a \to T_1 \to T_2 \to T_3 \to T_b$.



6. Air at 70 $^{\circ}$F (T_{b1}) and 1 atm is to be pumped through a straight 2-in (D) i.d. tube at a rate of 70 lb$_m$/hr (w). A section of the tube is to be heated to an inside wall temperature of 250 $^{\circ}$F (T_O) to raise the air temperature. The heated length is 20 ft (L). The physical properties of air are as follows: viscosity μ =0.05 lb$_m$/hr-ft, specific heat C_p =0.242 Btu/lb$_m$-$^{\circ}$F, and thermal conductivity $k = 0.018$ Btu/hr-ft-$^{\circ}$F. ***Calculate***: <u>(12% all)</u>

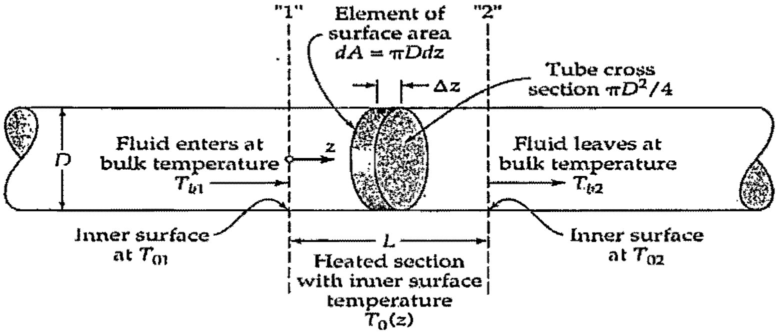
(a). The logarithmic mean heat transfer coefficient $h_{\ln}$. <u>4%</u>

(b). The bulk temperature of air at the exit of the heated region T_{b2}. <u>4%</u>

(c). The rate of heat flow Q. <u>4%</u>

Hint:

As shown in the following figure, a fluid flows through a circular tube of diameter D, in which there is a heated wall section of length L and varying inside surface temperature $T_O(z)$, going from T_{O1} to T_{O2}. The bulk temperature T_b of the fluid increases from T_{b1} to T_{b2} in the heated section.



BIRD: *Transport Phenomena, 2e*
Fig. 14.1-1 W-198

The logarithmic mean temperature difference $\Delta T_{\ln}$ and the logarithmic mean heat transfer coefficient $h_{\ln}$ are defined as:

$$Q = h_{\ln}(\pi D L)\Delta T_{\ln}$$

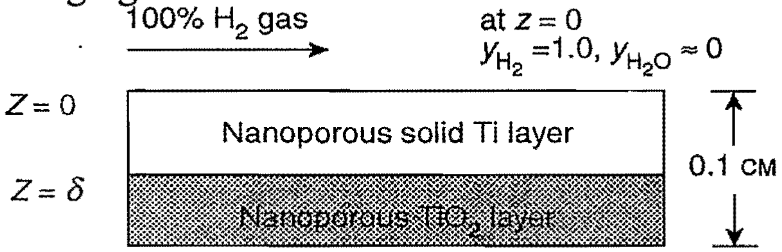
$$\Delta T_{\ln} = (T_0 - T_b)_{\ln} = [(T_{01} - T_{b1}) - (T_{02} - T_{b2})]/[\ln(T_{01} - T_{b1}) - \ln(T_{02} - T_{b2})]$$

where the rate of heat flow Q can also be calculated by:

$$Q = wC_p(T_{b2} - T_{b1})$$

$h_{\ln}$ can be estimated by the following correlations: for highly turbulent flow ($\mathrm{Re} > 20{,}000$), $Nu_{\ln} = 0.026\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3}$ and for laminar flow, $Nu_{\ln} = 1.86(\mathrm{Re}\,\mathrm{Pr}\,D/L)^{1/3}$. The dimensionless parameters are defined as: $\mathrm{Pr} = C_p\mu/k$, $\mathrm{Re} = D\,v_b\,\rho/\mu = 4w/(\pi D\mu)$, and $Nu_{\ln} = h_{\ln}D/k$.

7. As part of the manufacturing process for the fabrication of titanium-oxide-based solar panels, a layer of nonporous titanium oxide must be reduced to metallic titanium, Ti, by hydrogen gas as shown in the following figure: (12% all)



The reaction at the Ti/TiO_2 boundary is given by:

$$TiO_2(s) + 2H_2(g) \rightarrow Ti(s) + 2H_2O(g)$$

Let species A represent H_2 (g) and species B represent H_2O (g). Further assume: (1). The non-homogeneous reaction occurs only at the TiO_2/Ti surface, i.e. there is no reaction occurring when species A (H_2) diffuses in the Ti layer (R_A=0)；(2) The diffusion of species A (H_2) is under steady state and one-dimensional (*z*-direction) conditions.

(a). Using the following boundary conditions: $z=0$, $y_A=1.0$ and $z=\delta$, $y_A=0$, ***derive that*** $N_{A,z}=\dfrac{cD_{AB}}{\delta}$. 6%

Where c, D_{AB} are the gas phase concentration and diffusivity, respectively.

(b). Further consider a pseudo steady-state condition for the growth of the Ti layer (thickness δ). Using the following boundary conditions: $t=0$, $\delta=\delta_1$ and $t=\theta$, $\delta=\delta_2$, ***derive that*** $\theta=\dfrac{\rho_{Ti}/M_{Ti}}{cD_{AB}}(\delta_2^{\,2}-\delta_1^{\,2})$. 6%

Where ρ_{Ti}, M_{Ti} are the density and molecular weight of Ti, respectively.

Hint:

The general differential equation for mass transfer of species A：

$$\frac{\partial c_A}{\partial t}+\left[\frac{\partial N_{A,x}}{\partial x}+\frac{\partial N_{A,y}}{\partial y}+\frac{\partial N_{A,z}}{\partial z}\right]=R_A$$

Fick's equation of species A：

$$N_{A,z}=-cD_{AB}\frac{dy_A}{dz}+y_A(N_{A,z}+N_{B,z})$$

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100學年度碩士班暨碩士在職專班招生考試試題
系所：化材系
科目：材料科學導論(1)

1、Tabulated below are data that were gathered from a series of Charpy impact tests on a ductile cast iron:

Temperature（℃）	Impact Energy（J）
-25	123.8
-50	122.7
-75	115.1
-85	100.0
-100	73.2
-110	52.1
-125	26.3
-150	9.0
-175	6.1

（a）Plot the data as impact energy versus temperature（10%）

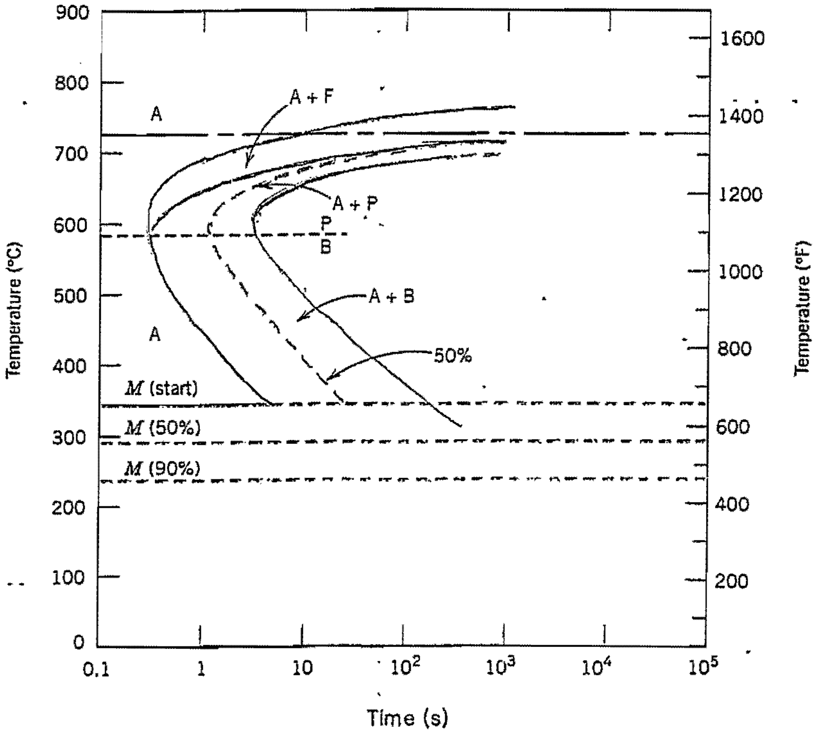
（b）Determine a ductile-to-brittle transition temperature as that temperature corresponding to the average of the maximum and minimum impact energy（10%）

2、Make a copy of the isothermal transformation diagram for a 0.46wt% C iron-carbon alloy（Figure 1）, and then sketch and label on this diagram the time-temperature paths to product the following microstructures:

（a）50% fine pearlite and 50% bainite （10%）

（b）50% martensite and 50% austenite （10%）

Figure 1



3、List major difference between deformation by twinning and deformation by slip relative to mechanism, condition of occurrence, and final result. (10%)

4. Please pick up the right answer from the following multiple-choice questions. (20%)

i. Which of these is an object made with polymers?（A）The outside of a computer, (B) A penny, (C) An oven-proof casserole dish, (D) A piece of paper

ii. What do you call a material that is hard but brittle and is a good insulator? (A) polymer, (B) semiconductor, (C) metal, (D) ceramic

iii. Motors inside cars are mostly made out of this material? (A) polymer, (B) ceramic, (C) metal, (D) none of the above

iv. Microchips inside computers are made with silicon which is an example of a (A) polymer, (B) semiconductor, (C) metal, (D) composite

v. The outside of a modern car is made from fiberglass which is a material called a (A) polymer, (B) semiconductor, (C) ceramic, (D) composite

vi. All plastics have a certain temperature above which they are soft and pliable, and below which they are hard and brittle. This is called（A）crystallization temperature，(B) glass transition temperature，(C) polymerization temperature，（D）first order transition temperature

vii. What unit is one millionth of a millimeter? (A) a meter, (B) a micron, (C) a nanometer, (D) a centimeter

viii. The Space Shuttle is covered with special tiles which prevent it from burning up upon its return to the atmosphere. These tiles must be a (A) metal, (B) polymer, (C) semiconductor, (D) ceramic

ix. Rigid plastics tend to be strong, resist deformation, but they tend not to be very tough, that is, they're （A）brittle，(B) soft，(C) stiff，(D) flexible

x. If one measures the area underneath the stress-strain curve, the number you get is something we call (A) stiffness，(B) hardness，(C) toughness，(D) modulus

5. (a)The covalent bond between two carbon atoms, C-C, is 370 kJ/mole(88 kcal/0.6 x 10^{24} bonds) The energy of light is $E = h\nu$, where h is Planck's constant(0.66 x 10^{-33} joule sec) and ν is the frequency of light. What wavelength λ is required to break a C-C bond? (10%)

(b)What is your comment on the relationship between the calculated λ and the degradation of plastics under sunlight? (10%)

6. Compute the density of copper, which has an atomic radius of 0.128 nm, an FCC crystal structure, and an atomic weight of 63.5 g/mol. (10%)

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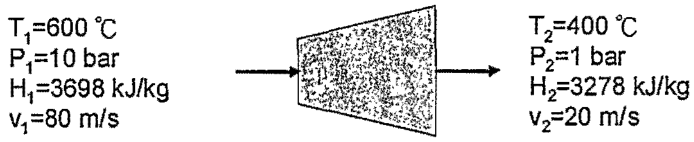
系所：化材系
科目：化工熱力學

1. Write out the expressions for Helmholtz free energy A and Gibbs free energy G, respectively. Explain their physical meanings. (10%)

2. Seam at 600℃ and 10 bar enters steadily an adiabatic turbine with a velocity of 80 m/s and a flow rate of 5 kg/s and leaves at 400℃ and 1 bar, with a velocity of 20 m/s. Determine the power output from the turbine. (20%)



3. A adiabatic device is designed to separate flowing air at 50℃ and 5 bar into two streams of equal mass, one at 80℃ and 2 bar, and the other at 20℃ and 3 bar. Air can be assumed to be an ideal gas with a constant heat capacity of C_p =29.3 J/ mol K. Is such a device possible? Explain why? (20%)

Hint: $\underline{S}(T_2,P_2)-\underline{S}(T_1,P_1)=C_p\ln(T_2/T_1)-R\ln(P_2/P_1)$

4. Consider a container of volume 2.0 L that is divided into two compartments of equal size. In the left compartment there is nitrogen at 1.0 atm and 25 °C; in the right compartment there is oxygen at the same temperature and pressure. Calculate the entropy and Gibbs energy of mixing when the partition is removed. Assume that the gases are ideal (15 %).

5. The partial molar volume of A at 298 K and 1 atm is found to fit the expression

$$V_A = 32.28 + 18.216\, a^{1/2}$$

Where V_A unit: cm^3/mole and a unit: mole A/ kg B. The molar volume of pure B (water) at 298 K and 1 atm is 18.079 cm^3/mole. Derive an equation for partial molar volume of B at 298 K and 1 atm (20 %).

6. Calculate ΔS (for the system) when the state of 2.50 moles nitrogen, assumed to be an ideal gas, is changed from 25 °C and 2.00 atm to 125 °C and 8.00 atm (15 %).

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系所：化材系
科目：化工動力學

1. In a continuous plug-flow tubular reactor (PFTR), feedstock of pure A is transformed into desired product B in the reaction of $A \rightarrow B$ at the flow-rate of 4 liter/min with $C_{A0} = 2$ moles/liter. However, there is a second reaction $A \rightarrow C$, which can also occur. Both reactions are first order and irreversible with $k_1 = 0.45\ \text{min}^{-1}$ and $k_2 = 0.05\ \text{min}^{-1}$. Find reactor volume ($V$), concentration of B ($C_B$), selectivity of B ($S_B$) and yield of B ($Y_B$) for 95% conversion of A. (20%)

2. For the reversible reaction $A \leftrightarrow B$, $r = k_f C_A - k_b C_B$, find the residence times for 50% conversion of A in a continuous stirred tank reactor (CSTR) and in a PFTR respectively, if $k_f = 0.7\ \text{min}^{-1}$, $k_b = 0.1\ \text{min}^{-1}$, $C_{A0} = 4$ moles/liter, feedstock flow-rate of 6 liter/min and $C_{B0} = 0$. (20%)

3. In a reaction rate expression, rate constant is usually presented as following:

$$k(T) = k_o \exp(-E/RT)$$

where E is the activation energy and k_o is the pre-exponential factor.

Please make descriptions to obtain E and k_o using "differential reactor" method. (10%)

4. The parallel reactions

$$A \rightarrow D$$
$$A \rightarrow U$$

react in a CSTR. The entering molar flow rates are F_{A0}=5 mol/min and F_{D0}=F_{U0}=0. The effluent molar flow rates are F_A=1 mol/min, F_D=3 mol/min, and F_U=1 mol/min. Determine (10%)

(a) instantaneous selectivity $S_{D/U}$ and overall selectivity $\tilde{S}_{D/U}$

(b) instantaneous Yield Y_D and overall Yield $\tilde{Y}_D$

5. The following liquid-phase reactions were carried out in a CSTR with the space time τ. (20%)

$3A \rightarrow B + C \qquad -r_{1A} = k_{1A}C_A$

$2C \rightarrow 3D \qquad r_{2D} = k_{2D}C_c$

$3B + 4D \rightarrow 3E \qquad r_{3E} = k_{3E}C_BC_D$

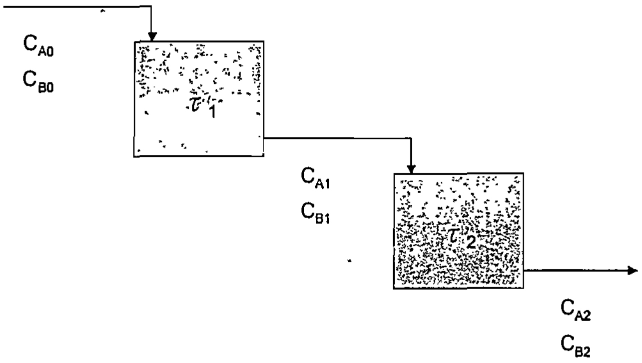
(a) What are the net rates of reaction for A, B, C, D, and E?

(b) If the inlet feed only includes species A (C_{A0}), what is the exit concentration of C?

6. The irreversible elementary reaction

$$A + B \rightarrow C$$

reacts in two CSTRs in series ($\tau_1 = 2.5\text{min}, \tau_2 = 5\text{min}$). The influent and effluent volumetric flow rate keep the same (change in volumetric flow rate is negligible). The feed ($C_{A0} = 1.0\text{M}$, $C_{B0} = 1.6\text{M}$) enters the first CSTR and the compositions in the first reactor are $C_{A1} = 0.4\text{M}$. Find the C_{B1}, C_{A2} and C_{B2} (20%)



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系所：化材系
科目：物理化學

1. Ammonia initially at 25℃and 1 bar pressure is heated at constant pressure until the volume has become three times of original one. Calculate (a) Q per mole, (b) W per mole, (c) ΔU per mole, and (d) ΔS per mole. Given: ammonia is considered to be an ideal gas. $C_p = 25.9+33.0 \times 10^{-3}T-30.5 \times 10^{-7}T^2$ in J/(Kmol) (20%)

2. Two blocks of the same metal with same size are at different temperatures, T_1 and T_2. Both metals are brought together and allowed to come to the same temperature. (a) Derive the entropy change (ΔS) for the above procedure with C_p, T_1, and T_2 if C_p is constant. (b) Is the above procedure spontaneous? (20%)

3. Please explain following items.

(a)Give a P-V chart of reversible Carnot Cycle and define the efficiency. (5%)
(b)Give a P-V chart of reversible Otto Cycle and define the efficiency. (5%)
(c)Nernst equation (5%)
(d)Debye temperature (5%)

4.Comelli et al. report the excess volume of mixing propionic acid with oxane at 313.15 K as $V^E = x_1 x_2 \{a_0 + a_1(x_1-x_2)\}$,where x_1 is the mole fraction of propionic acid, and x_2 that of oxane, $a_0 = -2.4697$ cm^{3}mol^{-1} and, $a_1 = 0.0608$ cm^{3}mol^{-1}. The density of propionic acid at this temperature is 0.97174 g cm^{-3} ; that of oxane is 0.86398 g cm^{-3}.

(a)Derive an expression for the partial molar volume of each component at this temperature(15%)

(b)Computer the partial molar volume for each component in an equimolar mixture(10%)

5.The excess Gibbs energy (G^E)of solutions of A and B at 300K was found to fit the expression

$$G^E = RT\,x\,(1-x)\{0.486 - 0.108\,(2x-1) + 0.019\,(2x-1)^2\}$$

Where x is the mole fraction of A . Calculate the Gibbs energy of mixing when a mixture of 2 mole of A and 3 mole of B is prepared. (15%)