1. (1) define $c_p$ and $c_v$ 

\[ c_p - c_v = \left( \frac{\partial V}{\partial T} \right)_p \left( \frac{P}{\alpha} + \frac{\partial U}{\partial V} \right)_T \] 

(10%) 

(2) derive that $c_p - c_v = \left( \frac{\partial V}{\partial T} \right)_p \left[ P + \left( \frac{\partial U}{\partial V} \right)_T \right]$ 

(10%) 

(3) compute $c_p - c_v$ of aluminum at 20°C. At this temperature, aluminum has the following properties: 

$c_p = 24.36 \text{ J/mole-K}$, the isobaric thermal expansivity $\alpha = \frac{1}{V} \left( \frac{\partial V}{\partial T} \right)_p$, the isothermal compressibility of a system $\beta = -\frac{1}{V} \left( \frac{\partial P}{\partial V} \right)_T$, atomic weight is 26.98 g/mole, density is 2.7 g/cm$^3$. 

(hint: $P = \left( \frac{\partial A}{\partial V} \right)_T$, $A = U - TS$, $\left( \frac{\partial S}{\partial V} \right)_T = \left( \frac{\partial P}{\partial T} \right)_V$) 

(10%) 

2. The virial equation of state for n-butane at 460 K is $Z = 1 + \frac{A}{V} + \frac{B}{V^2}$ in which $A = -265 \text{ cm}^3/\text{g-mole}$ and $B = 30250 \text{ cm}^4/\text{mole}^2$. Calculate the change in the Gibbs free energy when the volume of one mole of n-butane is increased from 100 to 500 cm$^3$ at 460 K. 

(10%) 

3. The specific heat of solid copper above 300K is given by $C_p = 22.64 + 6.28 \times 10^{-3}T \text{ J/mol K}$. By how much do the enthalpy and entropy increase on heating from 300 to 1358 K. 

(10%) 

4. (1) Please derive the relationship between Henry’s and Raoults’s laws for a binary A-B solution. (5%) (2) If A-B solution is an ideal solution and exhibits positive deviation characteristics, please draw a schematic diagram of activities of A vs $X_A$ (mole fraction of A). (5%) (3) Please describe the relationship of temperature and activity with this solution behavior. (5%) 

5. At 900 K, the reaction of NiO with Cl$_2$ gas is 

\[ \text{NiO(s) + Cl}_2(g) = \text{NiCl}_2(g) + \frac{1}{2} \text{O}_2(g) \] 

and 

\[ \Delta G^0 = -15,490 \text{ J} \] 

Calculate the total pressure as conversion rate of Cl$_2(g)$ is 90%. (10%) 

6. (1) At equilibrium state, a solution reaction is 

\[ aA + bB = cC + dD \] 

Please define the equilibrium constant for the reaction (5%). (2) At constant pressure and temperature, please describe the relationship of reaction constant and equilibrium constant with reaction direction. (5%)
7. For a binary A-B solution system, at constant temperature and pressure. (1) Please define system free energy. (5%) (2) Please discuss the stability of cure I and II in the figure. (10%)