1. From the data given below, calculate the equilibrium constant for the reaction $C + CO_2 = 2CO$ at 700°C and calculate the composition for the gas mixture for $p_{CO} + p_{CO_2} = 0.1$ and 10 atm.

   $C + O_2 = CO_2$ $\quad\quad \Delta G^\circ = -394040 - 0.837\ T\ J$

   $C + 1/2\ O_2 = CO$ $\quad\quad \Delta G^\circ = -114000 - 85.3\ T\ J$

   (15%)

2. Prove that (a) $(\partial U/\partial V)_T = T\alpha/\beta - P$

   (b) $(\partial U/\partial T)_P = C_P - PV\alpha$

   where $\alpha$ is the thermal expansion coeficient and $\beta$ is the isothermal compressibility.

   (10%)

3. 2.7 g of aluminum powder is reacted with oxygen under pressure to give $Al_2O_3$ in a constant volume combustion calorimeter at 25°C. The evolved heat is measured as 83.7 kJ.

   (a) Calculate $\Delta U$ and $\Delta H$ for the reaction

   $$2Al(s) + 3/2O_2(g) = Al_2O_3$$

   under these condition. Oxygen is regarded as an ideal gas.

   (b) The reaction had been carried out at a mean pressure of 50 atm. Calculate the value of $\Delta H^\circ_{298}$. The volume expansion coefficient $\alpha = (\partial V/\partial T)_P(1/V)$ is for aluminum $7 \times 10^{-5}$ and for aluminum oxide $2 \times 10^{-5}$. The molar volume $V_M$ is, 10.0 ml/mol for Al and 25.6 ml/mol for $Al_2O_3$.

   (25%)

4. Please calculate the standard entropy change for the following reaction (10%) at 25°C.

$$2Cu_{(s)} + 1/2\ O_{2(g)} = Cu_2O_{(s)}$$

$$\Delta G^0 = -40500 - 3.92\ T(\log T) + 29.5T \text{ cal}$$

5. Please answer "Yes" or "No" to each of the following questions. If your (20%) answer is "No", please further give the correct statement.

(a) A heat engine is a device that converts internal energy to work.

(b) Carnot cycle gave rise to the conclusion of the third law of Thermodynamics.

(c) In considering energy sharing and spatial orientation, the entropy expression is

$S_{total} = S_{thermal} + S_{conf.} = k \ln (t_{D(thermal)} + t_{D(conf.)})$

$t_D$ refers to the thermodynamic probability

(d) Work is a state property

6. The initial state of one mole of an ideal gas is p= 10 atm and T= 320K. (10%) Please calculate the entropy change in the gas for a process of constant volume decrease in the pressure to 1 atm.

7. The density of solid and liquid lead (Pb) at the normal melting temperature (10%) of 327°C are 10.94 and 10.65 g/cm$^3$, respectively. Please describe a method to lower the melting point of lead by 5°C.

Pb: 207 g/atom.