I didn’t get you set up very well for this test in terms of focusing your attention on particular topics, etc., so we will use a different approach. The test is one long problem with several parts. Hints are available as indicated at the point deductions indicated. Raise your hand or come see me if you need a hint. There is not a lot of text on the hints – hopefully enough to get you started if you get stuck.

Show your work on numerical questions to receive credit.

1. (10 points) Consider the reaction given below with the indicated thermodynamic data (letters do not refer to specific elements – they are generic):

   \[ 2 \text{A(g)} \rightleftharpoons \text{B(g)} \]

   | \( \Delta_f H^\circ \) (kJ/mol) | -22.5 | -48.3 |
   | \( S^\circ \) (J/molK) | 63.5 | 97.5 |
   | \( \Delta_f G^\circ \) (kJ/mol) | -6.3 | -16.3 |

   a. Would you expect this reaction to be spontaneous as written at 298 K? Explain your reasoning.

   b. Over what temperature range might you expect this reaction to be spontaneous assuming the thermodynamic parameters above do not change significantly with temperature? (*Hint 1 Available – 2 point deduction*)

   c. Find the value of \( K_f^\circ \) at 298 K.
2. (15 points) The reaction in problem 1 is set up initially in a 10.0-L container with 0.50 mol of A and 1.5 mol of B at 298 K. Assume both gases are ideal.

a. Find the initial pressure of each gas in the container.

b. Find the equilibrium pressure of each gas in the container.

(Hint 2 – 5 point deduction)
3. (8 points)
   a. Use the relationship
   \[
   K_p^\circ = K_c^\circ (RTc^\circ / P^\circ)^{\Delta n/\text{mol}}
   \]
   and your result for \(K_p^\circ\) to find \(K_c^\circ\).

   b. Use the relationship
   \[
   K_p^\circ = K_x (P / P^\circ)^{\Delta n/\text{mol}}
   \]
   and your result for \(K_p^\circ\) to find \(K_x\).

4. (6 points)
   a. Use your results from Problem 2 to calculate the molar concentration of each gas at equilibrium.

   b. Use the concentrations from Part a of this problem to find \(K_C^\circ\) and verify that it is equal to your answer from Problem 3a.
5. (6 points)
   a. Find the total pressure in the container at equilibrium from Problem 2.
   b. Find the mole fraction, \( x \), of each gas from your answers to Problem 2.
      \((Hint 3: \ 2 \ point \ deduction)\)
   c. Use the mole fractions from Part b of this problem to find \( K_x \) and verify that it is equal to your answer from Problem 3b.

6. (10 points) The van’t Hoff equation may be written as:
   \[
   \frac{d \ln K_p^\circ}{d(1/T)} = -\frac{\Delta H^\circ}{R}
   \]
   a. Carry out the integration of the van’t Hoff equation between limits of \( \ln K_{P,T1}^\circ \) at \( T_1 \) and \( \ln K_{P,T2}^\circ \) at \( T_2 \) assuming \( \Delta H^\circ \) does not change with temperature. \((Hint 4: \ 3 \ point \ deduction)\)
   b. Use the thermodynamic data, your value of \( K_p^\circ \), and your results from Problem 6a to find \( K_p^\circ \) at 500 K.
Potentially useful information:

\[ R = 8.314 \, \text{J/mol-K} = 0.08314 \, \text{L-bar/mol-K} \]

\[ \Delta_r G^o = -RT \ln K_p^o \]
Hint 1: \[ \Delta G = \Delta H - T\Delta S \]

Hint 2: \[ 2 \text{A(g)} \quad \rightleftharpoons \quad \text{B(g)} \]

Initial:

Change: \[-2x \quad x \]

Equilibrium

\[ \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

Hint 3:

\[ x_i = \frac{P_i}{P_{\text{tot}}} \]

Hint 4:

\[ d \ln K_p^\circ = -\frac{\Delta H^\circ}{R} d(1/T) \]

Integrate

Remember, \[ \int d(\text{anything}) = \text{anything} \]