1. Consider the following reaction and the thermodynamic data given on the last page of this document.

\[ 2 \text{SO}_2 (g) + \text{O}_2 (g) \rightarrow 2 \text{SO}_3 (g) \]

a. (6 points) Find \( \Delta H^\circ \), \( \Delta S^\circ \), and \( \Delta G^\circ \) for this reaction at 298 K.

b. (2 points) Is the reaction exothermic or endothermic?

c. (3 points) Is the reaction spontaneous at 298 K? Explain your reasoning.

d. (3 points) Will this reaction be spontaneous at all temperatures, no temperatures, above some temperature, or below some temperature? Explain your reasoning.

e. (2 points) If the reaction will be spontaneous above or below a particular temperature, what temperature is it? Show your work.
2. Continuing on with the same reaction from Problem 1.

   a. (4 points) Find the equilibrium constant for the reaction at 298 K. Show your work.

   b. (4 points) A vessel is mixed at 298 K and at equilibrium is found to contain $2.0 \times 10^{-8}$ atm of SO$_2$ and $5.0 \times 10^{-8}$ atm of O$_2$. What is the equilibrium concentration of SO$_3$? Show your work.

   c. (3 points) Based on your answers to Problem 1, would you expect the equilibrium to shift to the left or the right if the temperature is increased? Explain your reasoning.

   d. (4 points) What is the value of the equilibrium constant at 1000 K? Show your work.

   e. (3 points) Comparing your answers to parts b and d of Problem 2, how are these values of the equilibrium constant consistent with your prediction in part c? Explain.
3. Continuing on with the equilibrium from Problem 1.

   a. (4 points) What is \( E^\circ \) for the reaction at 298 K? Show your work.

   b. (4 points) What is \( E \) if the pressure of \( \text{SO}_2 \) is 2.5-atm, \( \text{O}_2 \) is 5-atm, and \( \text{SO}_3 \) is 0.050-atm? Show your work.

   c. (3 points) Is the system described in part b of this problem at equilibrium, shifting to the left, or shifting to the right? Explain your rationale.
Thermodynamic data and equations

<table>
<thead>
<tr>
<th>Species</th>
<th>$\Delta H^\circ$ (kJ/mol)</th>
<th>$\Delta G^\circ$ (kJ/mol)</th>
<th>$S^\circ$ (J/mol-K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_2$ (g)</td>
<td>0</td>
<td>0</td>
<td>205</td>
</tr>
<tr>
<td>$SO_2$ (g)</td>
<td>-297</td>
<td>-300</td>
<td>249</td>
</tr>
<tr>
<td>$SO_3$ (g)</td>
<td>-395</td>
<td>-370</td>
<td>256</td>
</tr>
</tbody>
</table>

$\Delta G = \Delta H - T \Delta S$

$\Delta G^\circ = -RT \ln K$

$\Delta G = -nFE$

$$E = E^\circ - \frac{0.0592}{n} \log Q$$

$F = 96485 \text{ C/mol}$

$R = 8.314 \text{ J/mol-K}$