CHEM 102 - Quiz 2 - Monday, Feb. 21, 2005

Your Name Here Please: __________________________

30 points total. Show all work for credit.

1) (15 pts.) For the reaction: \( \text{CS}_2(\text{liq}) + 3 \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{SO}_2(\text{g}) \)

\[
\Delta H^\circ_f \quad S^\circ \quad \Delta G^\circ_f \\
\text{CS}_2(\text{liq}) & 89.7 \text{ kJ/mol} & 151.3 \text{ J/K-mol} \\
\text{O}_2 & -393.5 \text{ kJ/mol} & 213.6 \text{ J/K-mol} \\
\text{CO}_2(\text{g}) & -393.5 \text{ kJ/mol} & 213.6 \text{ J/K-mol} \\
\text{SO}_2(\text{g}) & -296.8 \text{ kJ/mol} & 248.1 \text{ J/K-mol} \\
\]

a) Will the reaction be spontaneous at 298 K? Be quantitative in your answer.

b) Under what conditions will the reaction be spontaneous?

c) What is the value of \( \Delta G^\circ_f \) for \( \text{CS}_2(\text{liq}) \)?

\[
\Delta H^\circ_{\text{rxn}} = -(1\text{mole}\times89.7\text{kJ/mol}+3\text{mole}\times0 \text{kJ/mol})+(1\text{mole}\times-393.5\text{kJ/mol}+2\text{mole}\times-297\text{kJ/mol}) \\
= -(89.7 \text{kJ}) + (-987 \text{kJ}) = -1077 \text{kJ} \\
\Delta S^\circ_{\text{rxn}} = -(1\text{mole}\times151.3\text{J/K-mole-K}+3\text{mole}\times205\text{J/K-mole-K})+(1\text{mole}\times214.1\text{J/K-mole-K}+1\text{mole}\times248.1\text{J/K-mole-K}) \\
= -(766 \text{J/K}) + (710 \text{J/K}) = -56 \text{J/K} \\
\Delta G^\circ_{\text{rxn}} = \Delta H^\circ_{\text{rxn}} - T \Delta S^\circ_{\text{rxn}} = -1077 \text{kJ} -(298\text{K}\times-56 \text{J/K}) = -1,077,000 \text{J} - (-16,688 \text{J}) \\
= -1,060,000 \text{J} = -1,060 \text{kJ} \\
\]

Reaction is spontaneous at 298 K because \( \Delta G^\circ_{\text{rxn}} < 0 \)

b) At low temperatures. If the temperature was raised to 19,230 K the reaction would stop. Pretty darn hot!

c) \( \Delta G^\circ_{\text{rxn}} = -(1\text{mole}\times X \text{kJ/mol} + 3\text{mole}\times0 \text{kJ/mol})+(1\text{mole}\times-394 \text{kJ/mol}+2\text{mole}\times-300 \text{kJ/mol}) \\
= -1,060 \text{kJ} \\
-1060 \text{kJ} = -X \text{kJ} -994 \text{kJ} \\
X = +1060 \text{kJ} - 1022 \text{kJ} = +66 \text{kJ} \\
2) (15 pts) Initial rate data for the reaction \( 2 \text{A} + \text{B} \rightarrow \text{C} + \text{D} \) run at 298 K is found on the table below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[A]_{initial}</th>
<th>[B]_{initial}</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.050 M</td>
<td>0.100 M</td>
<td>7.0 M/sec</td>
</tr>
<tr>
<td>2</td>
<td>0.075 M</td>
<td>0.075 M</td>
<td>6.3 M/sec</td>
</tr>
<tr>
<td>3</td>
<td>0.150 M</td>
<td>0.100 M</td>
<td>21.5 M/sec</td>
</tr>
<tr>
<td>4</td>
<td>0.150 M</td>
<td>0.300 M</td>
<td>192.0 M/sec</td>
</tr>
</tbody>
</table>

a) What is the order of reaction for A? What is the order of reaction for B?

b) What is the value of the rate constant for this reaction?

c) What would the rate be if [A] = 1.5 M and [B] = 0.5 M?

d) What can you say about the mechanism of this reaction based on the data and your calculations?

a) Ratio Exp’ts 1 & 3: \[ \frac{7.0 \text{ M/sec}}{21.5 \text{ M/sec}} = k \frac{[0.050 \text{ M}]^m [0.100 \text{ M}]^n}{[0.150 \text{ M}]^m [0.100 \text{ M}]^n} \]

\[ 0.326 = (0.333)^m \text{ with rounding } m=1 = \text{Order of reaction for A} \]

Ratio Exp’ts 4 & 3: \[ \frac{192.0 \text{ M/sec}}{21.5 \text{ M/sec}} = k \frac{[0.150 \text{ M}]^m [0.300 \text{ M}]^n}{[0.150 \text{ M}]^m [0.100 \text{ M}]^n} \]

\[ 8.9 = (3.0)^n \text{ with rounding } n = 2 = \text{Order of reaction for B} \]

b) Rate = \( k [A]^1 [B]^2 \) Use any experiment to solve for \( k : 7.0 \text{ M/sec} = k (0.05 \text{ M})^1 (0.1 \text{ M})^2 \)

\[ k = 7.0 \text{ M/sec } / (0.05 \text{ M})^1 (0.1 \text{ M})^2 \]

\[ k = 1.4 \times 10^4 \text{ M}^2 \text{-sec}^{-1} \]

c) Rate = \( k [A]^1 [B]^2 = 1.4 \times 10^4 \text{ M}^2 \text{-sec}^{-1} (1.5)(0.5)^2 = 5250 \text{ M/sec} \)