1. Predict the signs of $\Delta G$, $\Delta H$, and $\Delta S$ for the following process.

Ammonium nitrate, NH$_4$NO$_3$, dissolves spontaneously and endothermically in water at 25°C.  

Homework Problem

$$\Delta G - \Delta H + \Delta S +$$
spontaneous   endothermic   more disorder: an aqueous solution is more disordered than an ionic solid and the solvent water

2. Estimate the melting point of an unknown substance in °C if the latent heat of fusion of the substance ($\Delta H_{\text{fus}}$) is 7.51 kJ/mol and the entropy change for the change in state from solid to liquid at its melting point ($\Delta S_{\text{fus}}$) is 20.50 J/K·mol. Enter your answer in °C with one decimal place.  

Homework Problem.  

$$\Delta G = 0$$

$$T = \frac{\Delta H}{\Delta S} = \frac{7.51 \times 10^3 \text{ J/mol}}{20.50 \text{ J/K·mol}} = 366 \text{ K} = 93.3^\circ \text{C}$$

3. Heating zinc sulfide at 400°C does not produce an appreciable amount of Zn.

ZnS(s) → Zn(s) + S(s)  \quad \Delta G^{\circ}_{\text{rxn}} = 198.3 \text{ kJ/mol}

However, the reaction can be coupled to the combustion of sulfur to form sulfur dioxide.

S(s) + O$_2$(g) → SO$_2$(g)  \quad \Delta G^{\circ}_{\text{rxn}} = −300.1 \text{ kJ/mol}

a) Calculate $\Delta G^\circ$ for the coupled reaction.  

$$\Delta G = 198.3 \text{ kJ/mol} + (−300.1 \text{ kJ/mol}) = −101.8 \text{ kJ/mol}$$

b) Is the coupled process spontaneous? Yes or no.  

Yes, the $\Delta G$ for the coupled reaction is negative.

4. True or False statements

a) For the first order reaction, A → products, if the concentration of A is increased by a factor of 3, the rate of reaction increases by a factor of 3.  

True

b) The typical units for reaction rate are L·mol$^{-1}$·s$^{-1}$.  

False, the typical units are M/s, which equals mol·L$^{-1}$·s$^{-1}$.

c) The value of the rate constant for a given reaction changes with temperature.  

True

d) For the first order reaction, A → products, the rate increases as reactant is consumed.  

False. For a first order reaction, Rate = $k[A]$. If [A] decreases, rate decreases.
5. Consider the oxidation of ammonia (NH\textsubscript{3}) by oxygen (O\textsubscript{2}) to form nitrogen dioxide (NO\textsubscript{2}) and water (H\textsubscript{2}O).

\[ 4\text{NH}_3(g) + 7\text{O}_2(g) \rightarrow 4\text{NO}_2(g) + 6\text{H}_2\text{O}(l) \]

Suppose that in this reaction nitrogen dioxide, NO\textsubscript{2}, is being formed at a rate of 13.8 moles liter\(^{-1}\) sec\(^{-1}\). At what rate (in moles liter\(^{-1}\) sec\(^{-1}\)) is oxygen used up? **Homework Problem.** [2 pts]

\[
13.8 \frac{M}{s} \frac{(\text{NO}_2)}{} \times \frac{7}{4} \frac{O_2}{\text{NO}_2} = 24.2 \text{ M/s}
\]

6. Consider the hypothetical reaction, A + B → C, with the rate law, Rate = \(k[A]^x[B]^y\). If the concentration of A is increased by a factor of 6 and the concentration of B is decreased by a factor of 2, by what factor will the rate of reaction increase. **Homework Problem.** [3 pts]

**Increase in rate** = \((6)^2(1/2) = 18\)

7. Consider the reaction

\[ X + Y \rightarrow Z \]

The following data are obtained at 360 K:

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>Initial rate of disappearance of X (M/s)</th>
<th>[X] (M)</th>
<th>[Y] (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.053</td>
<td>0.10</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>0.127</td>
<td>0.20</td>
<td>0.30</td>
</tr>
<tr>
<td>3</td>
<td>1.02</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>4</td>
<td>0.254</td>
<td>0.20</td>
<td>0.60</td>
</tr>
<tr>
<td>5</td>
<td>0.509</td>
<td>0.40</td>
<td>0.30</td>
</tr>
</tbody>
</table>

a) Determine the rate law of the reaction. [3 pts]

Compare Exp. 3 and 4  
\[
\frac{\text{Rate 3}}{\text{Rate 4}} = \left( \frac{[X]_3}{[X]_4} \right)^x
\]

\[
\frac{1.02 \text{ M/s}}{0.254 \text{ M/s}} = \left( \frac{0.40 \text{ M}}{0.20 \text{ M}} \right)^x
\]

\[4 = 2^x\]

\[x = 2\]

Compare Exp. 2 and 4  
\[
\frac{\text{Rate 4}}{\text{Rate 2}} = \left( \frac{[Y]_4}{[Y]_2} \right)^y
\]

\[
\frac{0.254 \text{ M/s}}{0.127 \text{ M/s}} = \left( \frac{0.60 \text{ M}}{0.30 \text{ M}} \right)^y
\]

\[2 = 2^y\]

\[y = 1\]

\[\text{Rate} = k[X]^2[Y]\]

b) What is the overall order of the reaction? [1 pt]

\[2 + 1 = 3\]

**Potentially Useful Information**

\[
\Delta G = \Delta H - T\Delta S
\]

\[K = \text{°C} + 273\]

\[\text{Rate} = k[A]^x[B]^y\]