Consider the combustion of one mole of hydrazine \( \text{(N}_2\text{H}_4) \) at 1 atm and 298K.

\[
\text{N}_2\text{H}_4(l) + 3 \text{ O}_2(g) \rightarrow 2 \text{ NO}_2(g) + 2 \text{ H}_2\text{O}(l)
\]

1. (3 points) Calculate the change in the standard reaction entropy for the system.

\[
\Delta S^\circ_{\text{rxn}} = \sum nS^\circ_{\text{products}} - \sum nS^\circ_{\text{reactants}}
\]
\[
\Delta S^\circ_{\text{rxn}} = [2(S^\circ_{\text{H}_2\text{O}(l)}) + 2(S^\circ_{\text{NO}_2(g)})] - [1(S^\circ_{\text{N}_2\text{H}_4(l)}) + 3(S^\circ_{\text{O}_2(g)})]
\]
\[
\Delta S^\circ_{\text{rxn}} = [2(70\text{J/molK}) + 2(240\text{J/molK})] - [1(12\text{J/molK}) + 3(205\text{J/molK})]
\]
\[
\Delta S^\circ_{\text{rxn}} = [620\text{J/molK}] - [627\text{J/molK}]
\]
\[
\Delta S^\circ_{\text{rxn}} = -7 \text{ J/K (for 1 mol of this reaction, which is what we have when we combust 1 mol hydrazine)}
\]

(OR \( \Delta S^\circ_{\text{rxn}} = -0.007 \text{ kJ/K} \))

Total of 3 pts:
+1 pts for correct equation/set-up
+2 points for correct answer
(or +3 pts for correct answer with some articulate work shown)

2. (3 points) Calculate the change in the standard reaction enthalpy for the system.

\[
\Delta H^\circ_{\text{rxn}} = \sum n \Delta H^\circ_{\text{ products}} - \sum n \Delta H^\circ_{\text{ reactants}}
\]
\[
\Delta H^\circ_{\text{rxn}} = [2(\Delta H^\circ_{\text{H}_2\text{O}(l)}) + 2(\Delta H^\circ_{\text{NO}_2(g)})] - [1(\Delta H^\circ_{\text{N}_2\text{H}_4(l)}) + 3(\Delta H^\circ_{\text{O}_2(g)})]
\]
\[
\Delta H^\circ_{\text{rxn}} = [2(-286\text{kJ/mol}) + 2(33\text{kJ/mol})] - [1(50\text{kJ/mol}) + 3(0\text{kJ/mol})]
\]
\[
\Delta H^\circ_{\text{rxn}} = [-506\text{kJ/mol}] - [50\text{kJ/mol}]
\]
\[
\Delta H^\circ_{\text{rxn}} = -556 \text{ kJ (for 1 mol of this reaction, which is what we have when we combust 1 mol hydrazine)}
\]

Total of 3 pts:
+1 pts for correct equation/set-up
+2 points for correct answer
(or +3 pts for correct answer with some articulate work shown)

3. (3 points) Calculate the change in standard Gibbs’ Free Energy for the system
\[ \Delta G_{\text{rxn}} = \Delta H_{\text{rxn}} - T(\Delta S_{\text{rxn}}) \]
\[ \Delta G_{\text{rxn}} = -556 \text{ kJ} - (298 \text{ kJ/K})(-0.007 \text{ kJ/K}) \]
\[ \Delta G_{\text{rxn}} = -533.914 \text{ kJ} \]

Total of 3 pts:
+1 pts for correct equation/set-up
+2 points for correct answer using the numbers provided from #1 and #2

4. (3 points) At what temperature will this reaction become spontaneous (or non-spontaneous)? Will the reaction be spontaneous above or below this temperature?

\[ 0 = \Delta G_{\text{rxn}} = \Delta H_{\text{rxn}} - T(\Delta S_{\text{rxn}}) \]
\[ 0 = \Delta H_{\text{rxn}} - T(\Delta S_{\text{rxn}}) \]
\[ 0 = -556 \text{ kJ} - (T)(-0.007 \text{ kJ/K}) \]
\[ T = \frac{-556 \text{ kJ}}{(-0.007 \text{ kJ/K})} \]
\[ T = 79,428.57 \text{ K} \]

The reaction will be spontaneous below this temperature.

Total of 3 pts:
+1 pts for correct equation/set-up
+1 points for correct answer using the numbers provided from #1 and #2
+1 point for correct analysis of spontaneity
(or +3 pts for correct answer with some articulate work shown and correct analysis of spontaneity)

5. (3 points) Will the sign on work be positive, negative or zero? Please explain your answer.

It will be positive. There are fewer gas moles in the products than in the reactants. The external pressure will do work ON the system and compress the system.

\[ \text{Work} = -\Delta n_{\text{gas}}RT = -(2 \text{ moles} - 3 \text{ moles})(8.314 \text{ J/molK})(298 \text{ K}) = +2,477.57 \text{ J} \]

Total of 3 pts:
+1 pts for correct sign
+2 pts for correct, logical explanation via words or through math

6. (3 points) If this same reaction was carried out in a bomb calorimeter, would the heat given off be more, less, or the same as your answer in #2? Explain why using words or a diagram.
There would be less heat given off in a bomb calorimeter (constant volume) because it no longer offsets positive work (since work is zero)

+1 for correct answer based on your answers for #2 and #5
+2 for reasonable explanation by words or diagram of your answer

7. (7 points) Match the following terms with the appropriate definition (by placing the corresponding letter in the provided ‘blank’).

a. Enthalpy  b. Entropy  c. First Law of Thermodynamics
d. Internal Energy  e. Specific Heat Capacity  f. Potential Energy
g. Kinetic Energy

_F_ energy of a system based on composition and position

_G_ energy of motion

_B_ energy dispersed relative to the temperature

_E_ intensive measure of heat flow relative to temperature change

_A_ heat flow at constant pressure

_D_ total energy of a system

_C_ conservation of energy