Directions: (1) Put your name (neatly) and signature on the free response part of the exam where indicated. (2) Each multiple choice question is actually 2 questions on your scanning sheet. If you are sure of an answer, put the same answer down for both questions for 5 pts. If you cannot decide between two answers, put one answer down for one question and the other answer down for the other question. If you get one correct you'll get half credit for 2.5 pts. If there is an ambiguous multiple choice question, use the last page to explain your answer. (3) Do NOT write on the envelope. (4) When finished, put the free response answers in the envelope with the scanning sheet. You can keep the multiple choice part - the answers will be given to you as you leave. (5) There are a total of 28 questions (16 actual questions).

PART 1

1&2. Which one of the following thermodynamic quantities is NOT a state function?

(a) P (b) T (c) \( \Delta H \) (d) \( q \) (e) \( q + w \)

3&4. When 1 mole of steam condenses to water, the entropy:

(a) increases (b) decreases (c) stays the same (d) equals 0 (e) is a negative value

5&6. Which of the following statements is(are) FALSE?

(I) \( \Delta H_{298}^{o} \) for HF(g) = \( \Delta H_{298}^{o} \) for HF(aq)
(II) When \( w = 0 \), \( \Delta E = q \) at constant volume.
(III) \( \Delta H = \Delta G + T \Delta S \) at constant temperature.

(a) I only (b) I and III (c) III only (d) II only (e) I and II
7&8. If work has a negative value in a reaction, we can deduce that:
    (a) work is done by the surroundings.
    (b) work is done on the system.
    (c) Δn_{gas} is less than zero for the reaction.
    (d) There are more moles of gaseous products than moles of gaseous reactants.
    (e) the reaction must not be spontaneous.

9&10. Melting is an example of a process for which AT ALL TEMPERATURES:
    (a) ΔH, ΔS, and ΔG must be negative.
    (b) ΔH, ΔS, and ΔG must be positive.
    (c) ΔH, ΔS only must be positive.
    (d) ΔH must be positive and ΔS must be negative.
    (e) ΔH must be negative and ΔS must be positive.

11&12. The correct name for C₂H₆ is:
    (a) ethene (ethylene)  
    (b) ethane
    (c) ethanol
    (d) ethyne (acetylene)
    (e) methane

13&14. For a certain process at 127°C, ΔG° = -16.20 kJ and ΔH° = -17.0 kJ. What is the entropy change for this process at this temperature?
    (a) -6.3 J/K  
    (b) +6.3 J/K  
    (c) -2.0 J/K  
    (d) +2.0 J/K  
    (e) -8.1 J/K
15&16. How much heat energy is liberated when 11.0 grams of manganese metal is converted to Mn$_2$O$_3$(s) at standard state conditions? $\Delta H^\circ_{\text{f} 298}$ of Mn$_2$O$_3$(s) is $-962.3 \text{ kJ/mol}$.

(a) 96.3 kJ  (b) 192 kJ  (c) 289 kJ  (d) 460. kJ  (e) 964 kJ

17&18. The normal boiling point of ethanol is 78°C. The $\Delta S$ for the following equilibrium is 122 J/K. Estimate the $\Delta H^\circ$ for the boiling of 1 mol of ethanol.

$$\text{C}_2\text{H}_5\text{OH}(\ell) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(g)$$

(a) +33.3 kJ  (b) -9.8 kJ  (c) +9.8 kJ  (d) -42.8 kJ  (e) +42.8 kJ

19&20. What is the internal energy of a system when 30 J of work was done on the system by the surroundings and the system released 40 J of heat?

(a) +70 J  (b) -70 J  (c) -10 J  (d) +10 J  (e) +120 J
21&22. A reaction in which $\Delta H^\circ = -200$ kJ and $\Delta S^\circ = +100$ J/K,

(a) is spontaneous at all temperatures.
(b) is nonspontaneous at all temperatures.
(c) could become spontaneous at higher temperatures.
(d) could become spontaneous at lower temperatures.
(e) Nothing can be said about the spontaneity of a reaction from the values of $\Delta H^\circ$ and $\Delta S^\circ$ only.

23&24. The following reaction occurred in a bomb calorimeter at 300 K. The heat generated in the reaction was 19.5 kJ/mol rxn. Calculate the $\Delta H_{rxn}$.

$$A(s) + 2B(g) \rightarrow C(g)$$

(a) +19.5 kJ/mol rxn  (b) +17.0 kJ/mol rxn  (c) -19.5 kJ/mol rxn  
(d) -17.0 kJ/mol rxn  (e) -22.0 kJ/mol rxn
25. The following reaction converts hydrogen sulfide and sulfur dioxide into sulfur:

\[ 2\text{H}_2\text{S}(g) + \text{SO}_2(g) \rightarrow 3\text{S}(s) + 2\text{H}_2\text{O}(l) \]

(5 pts) (a) Determine the enthalpy change, \( \Delta H^\circ \), for this reaction (in kJ/mol rxn) using the following equations with their enthalpies. Show all your work.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>( \Delta H^\circ ) (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) ( \text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) )</td>
<td>(-285.8)</td>
</tr>
<tr>
<td>(2) ( \text{H}_2(g) + \text{S}(s) \rightarrow \text{H}_2\text{S}(g) )</td>
<td>(-20.6)</td>
</tr>
<tr>
<td>(3) ( \text{S}(s) + \text{O}_2(g) \rightarrow \text{SO}_2(g) )</td>
<td>(-296.8)</td>
</tr>
</tbody>
</table>

(5 pts) (b) These three reactions in the box are very special reactions with special values of \( \Delta H^\circ \). Explain briefly what their values of \( \Delta H^\circ \) represent and why.
26. A 4.55 g sample of liquid acetone was completely burned in a bomb calorimeter in the presence of excess oxygen. The temperature of the water increased from 24.49°C to 26.25°C. The bomb has a heat capacity of 426 J/°C and the calorimeter contains 986 g of water. The specific heat of liquid water is 4.18 J/°C.

(a) Calculate the heat released (in kJ) for the reaction:

(b) Determine $\Delta E$ for the reaction (in kJ/mol acetone). If you don't know the formula for acetone, use C$_4$H$_{10}$ (l) and lose 3 points.

(c) Balance the combustion reaction using acetone (or C$_4$H$_{10}$ (l)) and calculate $\Delta n_{gas}$. No points deducted if you use C$_4$H$_{10}$. 
27. Consider the following reaction and standard molar enthalpy of formation data:

\[
2 \text{ ZnS (s)} + 3 \text{ O}_2 (g) \rightarrow 2 \text{ ZnO(s)} + 2 \text{ SO}_2 (g)
\]

\[
\Delta H^{\circ}_{298} (\text{kJ/mol}) \quad -205.6 \quad 0 \quad -348.3 \quad -296.8
\]

(5 pts) (a) What is the enthalpy change per mole of ZnO in the reaction at 298 K and 1 atm pressure? Show work.

(5 pts) (b) How many grams of ZnO are produced if 455 J of heat are released in the reaction? Show your work.
28. In a short paragraph, explain how the following diagram relates to the importance of state functions in chemical thermodynamics. Use the concept of $\Delta H_{\text{rxn}}$ to illustrate your points.