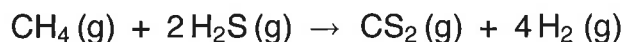

Spontaneity of Reaction

Worksheet A

A. Circle the correct answer(s).

- Which of the following processes would you expect to be spontaneous?
 - Dissolving NaCl in water at 25°C.
 - Vaporizing water at 100°C.
 - Melting candle wax at 200°C.
 - Dry ice, CO₂ (s), subliming at 25°C.
 - Making sugar (C₁₂H₂₂O₁₁) from water and carbon at 25°C.
- A reaction for which enthalpy and entropy have the same sign
 - is spontaneous at high T.
 - is spontaneous at low T.
 - can never be spontaneous.
 - is spontaneous if the temperature changes in the right direction,
 - is always spontaneous.
- For a reaction, $\Delta G^\circ = -70.0$ kJ at 298 K and + 10.0 kJ at 400 K. For this reaction
 - $\Delta S^\circ > 0$, $\Delta H^\circ > 0$
 - $\Delta S^\circ > 0$, $\Delta H^\circ < 0$
 - $\Delta S^\circ < 0$, $\Delta H^\circ > 0$
 - $\Delta S^\circ < 0$, $\Delta H^\circ < 0$

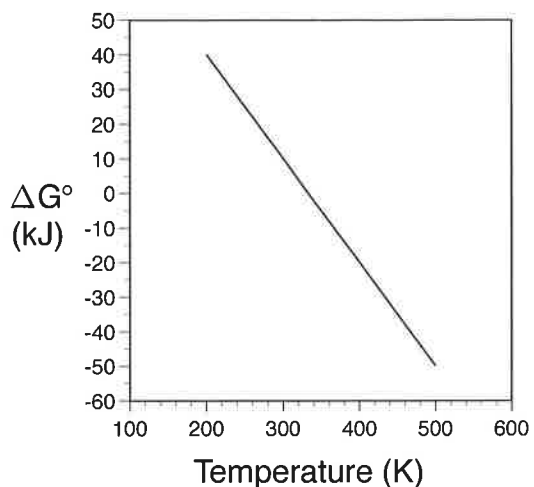
4. The following reaction



is endothermic. This reaction can be predicted to be spontaneous

- at low T only.
 - at high T only.
 - at all T.
 - at no T.
5. Which statements are true about entropy?
- As is true with enthalpies, absolute entropy values cannot be determined.
 - Entropy always increases during a phase change.
 - At 0 K, a perfect crystal has $S = 0$.
 - Entropy usually increases when a molecule is broken into two small molecules.

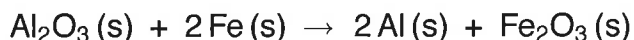
B. Consider the graph below.



1. Describe the relationship between the spontaneity of the process and temperature.
2. Is the reaction exothermic?
3. Is $\Delta S^\circ > 0$?
4. At what temperature is the reaction at standard conditions likely to be at equilibrium?
5. ~~What is K for the reaction at 27°C?~~

C. At what temperature will acetone boil if $\Delta H_{\text{vap}} = 30.3 \text{ kJ/mol}$, and $\Delta S_{\text{vap}} = 92.0 \text{ J/mol}\cdot\text{K}$?

D. Consider the reaction



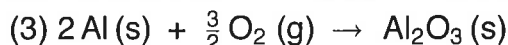
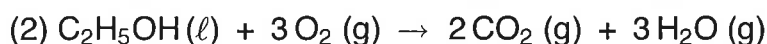
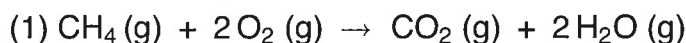
1. Is the reaction spontaneous at 100°C?
2. Is the spontaneity of the reaction temperature dependent? If so, at what temperature will the reaction be spontaneous?
3. Does the pressure have an effect on the spontaneity of this reaction?

Spontaneity of Reaction

Worksheet C

A. Circle the correct answer(s).

1. Consider the following exothermic reactions.

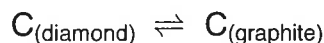


- ΔS for reaction (1) is zero because $\Delta n_g = 0$.
 - ΔS for (2) is most probably positive.
 - Equation (3) has a negative ΔS .
 - Equation (2) is certainly spontaneous.
 - The equations can be ranked (3) < (1) < (2) in terms of increasing ΔS .
2. Which statements about free energy are true?
- A combustion reaction producing heat and more moles of gas than are consumed will have a ΔG more negative than ΔH .
 - Reactions where $\Delta G < 0$ will occur spontaneously and rapidly.
 - When $\Delta G = 1$, the reaction is at equilibrium.
 - Any form of each pure element is assigned ΔG_f° .
 - ~~When $Q = 1$, $\Delta G = \Delta G^\circ$~~
3. For the reaction



However, at room temperature and standard pressure ($P = 1 \text{ atm}$), one does not observe diamond turning into graphite. An explanation for this is that

- a. the reaction is at equilibrium.



Since the rate of the forward reaction is the same as the rate of the reverse reaction, no change is visible.

- diamond is thermodynamically stable.
- spontaneity does not imply rate, i.e., the reaction is occurring at such a slow rate that the change is not noticeable.
- diamond does become graphite but the rate at which graphite becomes diamond is much faster.
- allotropes do not follow the rules of free energy.

4. A solid and liquid are mixed. Observations include the following:
- The solid disappears completely.
 - The beaker feels warmer to the touch after the compounds are mixed.
 - A gas is evolved.

One can state with a high degree of accuracy that

- a. the reaction is endothermic.
 - b. ΔS is positive.
 - c. the reaction is spontaneous.
 - d. the sign of ΔG is temperature dependent.
 - e. ~~K < 1~~
5. For the reaction



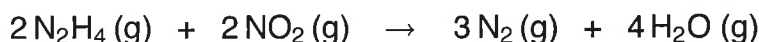
- a. The reaction is nonspontaneous.
- b. When equilibrium is reached, the reaction mixture will be mostly C.
- c. At equilibrium, only A and B will be in the reaction mixture.
- d. $A + B \rightarrow C$ is exothermic.
- e. $C \rightarrow A + B$ is spontaneous.

~~B. Calculate ΔG at 25°C for the reaction—~~



~~when $[\text{NH}_3] = 0.10$, $[\text{NH}_4^+] = 0.10$, $\text{pH} = 12.7$ and K_a for $\text{NH}_4^+ = 5.6 \times 10^{-10}$.~~

C. For the reaction



the following thermodynamic data is available:

	ΔH_f° (kJ/mol)	S° (kJ/mol-K)
N_2H_4	95.0	0.2385
NO_2	33.84	0.2404
N_2	0	0.1915
$\text{H}_2\text{O}(\text{g})$	-241.8	0.1887

~~Calculate the partial pressure of steam at 100°C at the point in the reaction when $P_{\text{N}_2} = 2.5 \text{ atm}$, $P_{\text{N}_2\text{H}_4} = P_{\text{NO}_2} = 1.0 \times 10^{-3} \text{ atm}$ and $\Delta G = -1264.6 \text{ kJ}$.~~

Determine ΔG for this reaction at 25°C. What does the sign of ΔG indicate?