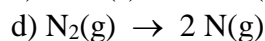
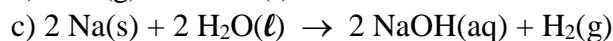
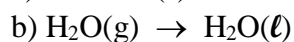
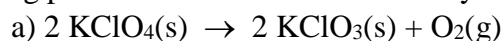


Problems, Chapter 14 (without solutions)

1) Give the correctly balanced formation reactions for each of the following pure chemical substances. a) $\text{HCl}(\text{g})$; b) $\text{C}_6\text{H}_6(\ell)$; c) $\text{Fe}(\text{NO}_3)_3(\text{s})$

2) (14.8) How does the entropy of a system change for each of the following processes? a) A solid melts; b) A liquid freezes; c) A liquid boils; d) A vapor is converted into a solid; e) A vapor condenses into a liquid; f) A solid sublimes; g) A molecular solid dissolves in water.

3) (14.10) Predict whether the entropy change is positive or negative for each of the following processes. Give the reasons for your predictions.

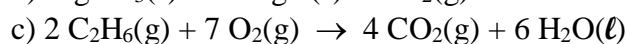
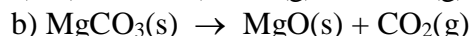
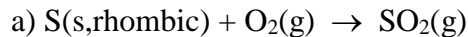


4) 0.100 moles of an ideal gas expands from an initial volume $V_i = 1.000 \text{ L}$ to a final volume $V_f = 4.000 \text{ L}$ and at a constant temperature $T = 300. \text{ K}$. Would you expect ΔS for the process to be positive, zero, or negative? Justify your answer.

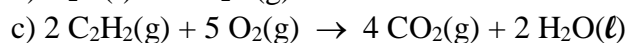
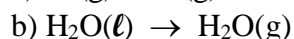
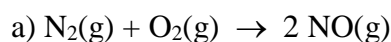
5) For each pair of substances, choose the one you expect to have the higher standard molar entropy (S°) at $25. \text{ }^\circ\text{C}$. Explain the reason for your choice. a) $\text{NaNO}_3(\text{s})$ or $\text{NaNO}_3(\text{aq})$; b) $\text{CH}_4(\text{g})$ or $\text{CH}_3\text{CH}_3(\text{g})$; c) $\text{Br}_2(\ell)$ or $\text{Br}_2(\text{g})$; d) $\text{Br}_2(\text{g})$ or $\text{F}_2(\text{g})$; e) $\text{PCl}_3(\text{g})$ or $\text{PCl}_5(\text{g})$; f) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3(\text{g})$ or $\text{SO}_2(\text{g})$

6) State the third law of thermodynamics and explain its significance.

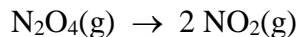
7) (14.14) Using the data in Appendix 2, calculate the standard entropy change for the following reactions at $T = 25. \text{ }^\circ\text{C}$.



8) (14.30) Using the data in Appendix 2, calculate $\Delta G^\circ_{\text{rxn}}$ for each of the following reactions at $25. \text{ }^\circ\text{C}$.



9) Consider the following chemical reaction, carried out at $T = 298$. K



Thermochemical data for the reactant and product are given below (given at $T = 298$. K).

substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S° (J/mol·K)
$\text{NO}_2(\text{g})$	33.85	51.8	240.46
$\text{N}_2\text{O}_4(\text{g})$	9.66	98.29	304.3

a) Find $\Delta H^\circ_{\text{rxn}}$, $\Delta G^\circ_{\text{rxn}}$, and $\Delta S^\circ_{\text{rxn}}$ for the above reaction.

b) Based on the definition of free energy, we expect $\Delta G^\circ_{\text{rxn}} = \Delta H^\circ_{\text{rxn}} - T \Delta S^\circ_{\text{rxn}}$.

Using your answer in part a, check to see if this is true for the above reaction.

c) Find $\Delta S^\circ_{\text{sys}}$, $\Delta S^\circ_{\text{surr}}$, and $\Delta S^\circ_{\text{univ}}$ for the above reaction.

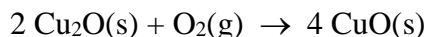
d) Using the information above there are two ways in which we can decide whether the above reaction is spontaneous at constant pressure and a constant temperature $T = 298$. K. What are they? Is the above reaction spontaneous at $T = 298$. K and constant pressure? Explain.

e) Is there a temperature where $\text{NO}_2(\text{g})$ and $\text{N}_2\text{O}_4(\text{g})$ exist at equilibrium for standard conditions ($p(\text{NO}_2) = p(\text{N}_2\text{O}_4) = 1.00$ atm)? If so, at what temperature does this occur?

10) Thermodynamic data for several pure chemical substances are given below (at $T = 298.0$ K).

Substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S° (J/mol·K)
$\text{CuO}(\text{s})$	- 157.3	- 129.7	42.63
$\text{Cu}_2\text{O}(\text{s})$	- 168.6	- 146.0	93.14
$\text{O}_2(\text{g})$	0.0	0.0	205.14

a) Using the above information, find the values for $\Delta H^\circ_{\text{rxn}}$, $\Delta G^\circ_{\text{rxn}}$, and $\Delta S^\circ_{\text{rxn}}$ for the following reaction, at $T = 298$. K.



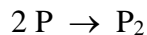
b) Find $\Delta S^\circ_{\text{sys}}$, $\Delta S^\circ_{\text{surr}}$, and $\Delta S^\circ_{\text{univ}}$ for the above reaction at $T = 298.0$ K.

c) Will the above reaction be spontaneous for standard conditions at $T = 298.0$ K?

Justify your answer?

11) Predict the spontaneity of a reaction (and the temperature dependence of the spontaneity) for each possible combination of signs for ΔH and ΔS (for the system).

12) Consider the formation of a dimeric protein P_2 by the process



At $T = 25. \text{ }^\circ\text{C}$, we have $\Delta H^\circ_{\text{rxn}} = 17.0 \text{ kJ/mol}$ and $\Delta S^\circ_{\text{rxn}} = 60.0 \text{ J/mol}\cdot\text{K}$.

- Is dimerization favored for standard conditions at this temperature?
- Comment on the effect of lowering the temperature. At what temperature (if any) would dimerization not be favored for standard conditions?

13) Given the values of $\Delta H^\circ_{\text{rxn}}$, $\Delta S^\circ_{\text{rxn}}$, and T below, determine ΔS_{univ} and predict whether or not each reaction will be spontaneous.

- $\Delta H^\circ_{\text{rxn}} = -95. \text{ kJ/mol}$, $\Delta S^\circ_{\text{rxn}} = -157. \text{ J/mol}\cdot\text{K}$, $T = 298. \text{ K}$
- $\Delta H^\circ_{\text{rxn}} = -95. \text{ kJ/mol}$, $\Delta S^\circ_{\text{rxn}} = -157. \text{ J/mol}\cdot\text{K}$, $T = 855. \text{ K}$

14) For each reaction calculate $\Delta H^\circ_{\text{rxn}}$, $\Delta S^\circ_{\text{rxn}}$, and $\Delta G^\circ_{\text{rxn}}$ at $25. \text{ }^\circ\text{C}$, and state whether or not the reaction is spontaneous. If the reaction is not spontaneous, would a change in temperature make it spontaneous? If so, should the temperature be raised or lowered from $25. \text{ }^\circ\text{C}$? Data for this problem are found in Appendix 2.

- $2 \text{ CH}_4(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g}) + \text{H}_2(\text{g})$
- $2 \text{ NH}_3(\text{g}) \rightarrow \text{N}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$

15) Using the data in Appendix 2, predict the normal boiling point temperature for $\text{Br}_2(\ell)$.

16) It takes the addition of 3348. J of heat to convert 10.00 g of n-hexane (C_6H_{14} , MW = 86.18 g/mol) from a liquid to a vapor at the normal boiling point, $T = 69. \text{ }^\circ\text{C}$ and $p = 1.000 \text{ atm}$. Based on this information find $\Delta H^\circ_{\text{vap}}$, $\Delta G^\circ_{\text{vap}}$, and $\Delta S^\circ_{\text{vap}}$ for this process and the conditions that are given in the problem.

17) (14.41) The normal melting point for ammonia (NH_3) is $-77.7 \text{ }^\circ\text{C}$. Predict the signs of ΔH , ΔS , and ΔG of the system for the following processes at 1.00 atm: a) ammonia melts at $-60.0 \text{ }^\circ\text{C}$; b) ammonia melts at $-77.7 \text{ }^\circ\text{C}$; c) ammonia melts at $-100.0 \text{ }^\circ\text{C}$.