

**CHEM 1423**  
**Chapter 20**  
**Homework Questions**

**TEXTBOOK HOMEWORK**

- 20.14** Without using Appendix B predict the sign of  $\Delta S^\circ$  for
- $\text{CaCO}_3(\text{s}) + 2 \text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
  - $2 \text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$
  - $2 \text{KClO}_3(\text{s}) \rightarrow 2 \text{KCl}(\text{s}) + 3 \text{O}_2(\text{g})$
- 20.16** Predict the sign of  $\Delta S$  for each process:
- $\text{C}_2\text{H}_5\text{OH}(\text{g})$  (350 K and 500 torr)  $\rightarrow$   $\text{C}_2\text{H}_5\text{OH}(\text{g})$  (350 K and 250 torr)
  - $\text{N}_2(\text{g})$  (298 K and 1 atm)  $\rightarrow$   $\text{N}_2(\text{aq})$  (298 K and 1 atm)
  - $\text{O}_2(\text{aq})$  (303 K and 12 atm)  $\rightarrow$   $\text{O}_2(\text{g})$  (303 K and 12 atm)
- 20.21** Without consulting Appendix B, arrange each group in order of increasing molar entropy ( $S^\circ$ ):
- Glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ), Sucrose ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ), Ribose ( $\text{C}_5\text{H}_{10}\text{O}_5$ )
  - $\text{CaCO}_3$ ,  $\text{Ca} + \text{C} + (3/2) \text{O}_2$ ,  $\text{CaO} + \text{CO}_2$
  - $\text{SF}_6(\text{g})$ ,  $\text{SF}_4(\text{g})$ ,  $\text{S}_2\text{F}_{10}(\text{g})$
- 20.28** For each reaction, predict the sign and find the value of  $\Delta S^\circ$ :
- $3 \text{NO}(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g}) + \text{NO}_2(\text{g})$
  - $3 \text{H}_2(\text{g}) + \text{Fe}_2\text{O}_3(\text{s}) \rightarrow 2 \text{Fe}(\text{s}) + 3 \text{H}_2\text{O}(\text{g})$
  - $\text{P}_4(\text{s}) + 5 \text{O}_2(\text{g}) \rightarrow \text{P}_4\text{O}_{10}(\text{s})$
- 20.40** Calculate  $\Delta G^\circ$  for each reaction using  $\Delta G_f^\circ$  values:
- $2 \text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2 \text{MgO}(\text{s})$
  - $2 \text{CH}_3\text{OH}(\text{g}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g})$
  - $\text{BaO}(\text{s}) + \text{CO}_2(\text{g}) \rightarrow \text{BaCO}_3(\text{s})$
- 20.46** One reaction used to produce small quantities of pure  $\text{H}_2$  is
- $$\text{CH}_3\text{OH}(\text{g}) \rightarrow \text{CO}(\text{g}) + 2 \text{H}_2(\text{g})$$
- Determine  $\Delta H^\circ$  and  $\Delta S^\circ$  for the reaction at 298 K
  - Assuming that these values are relatively independent of temperature, calculate  $\Delta G^\circ$  at 28 °C, 128 °C, and 228 °C
  - What is the significance of the different values of  $\Delta G^\circ$

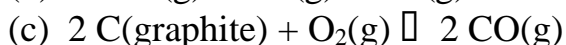
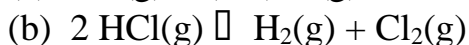
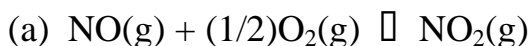
**20.48** Use  $\Delta H^\circ$  and  $\Delta S^\circ$  values for the following process at 1 atm to find the normal boiling point of  $\text{Br}_2$ :  $\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$

**20.51** The U.S. government requires automobile fuels to contain a renewable component. Fermentation of glucose from corn yields ethanol, which is added to gasoline to fulfill this requirement.

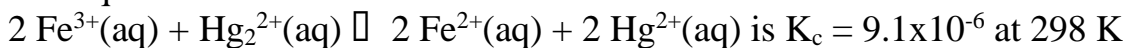


Calculate  $\Delta H^\circ$ ,  $\Delta S^\circ$ , and  $\Delta G^\circ$  for the reaction at 25 °C. Is the spontaneity of this reaction dependent on T? Explain.

**20.56** Calculate K at 298 K for each reaction:



**20.64** The equilibrium constant for the reaction



(a) What is  $\Delta G^\circ$  at this temperature?

(b) If standard-state concentrations of the reactants and products are mixed, in which direction does the reaction proceed?

(c) Calculate  $\Delta G$  when  $[\text{Fe}^{3+}] = 0.20 \text{ M}$ ,  $[\text{Hg}_2^{2+}] = 0.010 \text{ M}$ ,  $[\text{Fe}^{2+}] = 0.010 \text{ M}$ , and  $[\text{Hg}^{2+}] = 0.025 \text{ M}$ .

In which direction will the reaction proceed to achieve equilibrium?

**20.74** (a) Write a balanced equation for the gaseous reaction between  $\text{N}_2\text{O}_5$  and  $\text{F}_2$  to form  $\text{NF}_3$  and  $\text{O}_2$ .

(b) Determine  $\Delta G^\circ_{\text{rxn}}$

(c) Find  $\Delta G_{\text{rxn}}$  at 298 K if  $P_{\text{N}_2\text{O}_5} = P_{\text{F}_2} = 0.20 \text{ atm}$ ,  $P_{\text{NF}_3} = 0.25 \text{ atm}$  and  $P_{\text{O}_2} = 0.50 \text{ atm}$

## SUPPLEMENTARY HOMEWORK

S1. If a reaction is spontaneous at any temperature, then  $\Delta H^\circ$  is \_\_\_\_\_ and  $\Delta S^\circ$  is \_\_\_\_\_.

- a. positive; positive
- b. positive; negative
- c. zero; positive
- d. negative; positive
- e. negative; negative

S2. At constant  $T$  and  $P$ , in which of the following situations will the reaction never be spontaneous?

- a.  $\Delta H > 0$  and  $\Delta S < 0$
- b.  $\Delta H > 0$  and  $\Delta S > 0$
- c.  $\Delta H < 0$  and  $\Delta S < 0$
- d.  $\Delta H < 0$  and  $\Delta S > 0$
- e. none of the above

S3. A reaction is exothermic and has a negative value of  $\Delta S^\circ$ . The value of  $\Delta G^\circ$  for this reaction is therefore:

- a. negative at all temperatures.
- b. positive at all temperatures.
- c. positive above  $0^\circ\text{C}$  and negative below  $0^\circ\text{C}$ .
- d. positive above a certain temperature and negative below it.
- e. negative above a certain temperature and positive below it.

S4. The reaction  $A \rightarrow B$  is **exergonic** at  $25^\circ\text{C}$  and the enthalpy change is  $+20\text{ kJ}$ . What can be concluded about the entropy change for this reaction?

- a.  $\Delta S > +67\text{ J/K}$
- b.  $\Delta S > +800\text{ J/K}$
- c.  $\Delta S < -67\text{ J/K}$
- d. No conclusion can be made about  $\Delta S$

- S5. For the **endergonic** reaction  $C \rightarrow D$ ,  $\Delta S = +20 \text{ J/K}$ . For this reaction,
- $\Delta G < 0$  &  $\Delta H < 0$
  - $\Delta G > 0$  &  $\Delta H < 0$
  - $\Delta G < 0$  &  $\Delta H > 0$
  - $\Delta G > 0$  &  $\Delta H > 0$

S6. Consider a sample containing 322 grams of toluene ( $C_6H_5CH_3$ ,  $M = 92$ ).

Quantity	$T_m$	$T_b$	$\Delta H_{fus}^\circ$	$\Delta H_{vap}^\circ$	$\Delta S_{fus}^\circ$	$\Delta S_{vap}^\circ$
Value	-95 °C	+111 °C	6.64 kJ/mol	38.1 kJ/mol	37.3 J/mol-K	99.2 J/mol- K

(a) Calculate  $\Delta S_{sys}$ ,  $\Delta S_{surr}$  and  $\Delta S_{univ}$  for the vaporization of 322 grams of toluene at:

(1) 130 °C, (2) 111 °C, (3) 90 °C

(b) Calculate  $\Delta G^\circ$  for the vaporization of 322 grams of toluene at:

(1) 130 °C, (2) 111 °C, (3) 90 °C

(c) Calculate  $\Delta S_{sys}$ ,  $\Delta S_{surr}$  and  $\Delta S_{univ}$  for the freezing (crystallization) of 322 grams of toluene at:

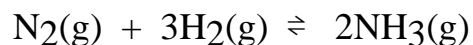
(1) -115 °C, (2) -95 °C, (3) -75 °C

(d) Calculate  $\Delta G^\circ$  for the freezing (crystallization) of 322 grams of toluene at:

(1) -115 °C, (2) -95 °C, (3) -75 °C

S7. A certain reaction has  $\Delta H^\circ = +177.8 \text{ kJ}$ , and  $\Delta S^\circ = +160.5 \text{ J/K}$ . Above or below what temperature (in °C) does it become spontaneous ?

S8. For the reaction shown,  $\Delta G^\circ = -32.8 \text{ kJ}$  at  $25^\circ\text{C}$ .



- Calculate the equilibrium constant for this reaction at  $25^\circ\text{C}$ .
- Is a mixture of the three gases where  $p_{\text{N}_2} = 3.5 \text{ bar}$ ,  $p_{\text{H}_2} = 1.2 \text{ bar}$ , and  $p_{\text{NH}_3} = 0.22 \text{ bar}$  at equilibrium? Justify your answer.
- What is the value of  $\Delta G$  under the conditions of part b?

S9. For the reaction,  $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ ,  $\Delta H^\circ = +178 \text{ kJ/mol}$  and  $\Delta S^\circ = +161 \text{ J/mol-K}$ .

- What is the value of  $\Delta G^\circ$  at  $25^\circ\text{C}$ ?
- What is the value of  $\Delta G^\circ$  at  $1500^\circ\text{C}$ ?
- At what temperature, in  $^\circ\text{C}$ , are the reactants and products in equilibrium?  
(i.e.  $\Delta G^\circ = 0$ )

S10. A hypothetical polypeptide, PP, has two structural forms,  $\text{PP}(\alpha)$  and  $\text{PP}(\beta)$ . For the transition,  $\text{PP}(\alpha) \rightarrow \text{PP}(\beta)$ , the entropy change is  $-120 \text{ J/mol-K}$  and the enthalpy change is  $-42 \text{ kJ/mol}$ .

This transition is spontaneous \_\_\_\_\_ (above or below) \_\_\_\_\_  $^\circ\text{C}$ .