

## Worksheet

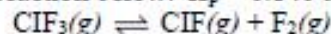
- 1) A chemical company claims that they are able to produce a certain product through a thermodynamically unfavored process. Explain how this is possible.
- 2) For a certain reaction  $\Delta G^\circ$  was found to be +32 kJ. What can be said about the relative proportion of reactants and products when the system is at equilibrium?
- 3) For a certain reaction  $\Delta H^\circ = -20$  kJ/mol and  $\Delta S^\circ = -75$  kJ/mol.
  - a. Without using your calculator, determine whether or not the process is thermodynamically favorable.
  - b. Does the equilibrium lie to the left, the right, or close to the middle? Justify your answer.
- 4) For the reaction below,  $\Delta H^\circ = -305.3$  kJ/mol and  $\Delta S^\circ = -155.2$  J/molK.
$$\text{Ni}(s) + \text{Cl}_2(g) \rightleftharpoons \text{NiCl}_2(s)$$
  - a. Calculate the equilibrium constant,  $K_{\text{eq}}$ , at 25.0°C.
  - b. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.
  - c. What is the partial pressure of  $\text{Cl}_2(g)$  at equilibrium?
- 5) For the reaction below,  $\Delta H^\circ = 178.1$  kJ/mol and  $\Delta S^\circ = 160.5$  J/molK.
$$\text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g)$$
  - a. Calculate the equilibrium constant,  $K_{\text{eq}}$ , at 25°C.
  - b. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.
  - c. What is the partial pressure of  $\text{CO}_2(g)$  at equilibrium?
- 6) For the reaction below,  $\Delta H^\circ = -537.2$  kJ/mol and  $\Delta S^\circ = 13.7$  J/molK.
$$\text{H}_2(g) + \text{F}_2(g) \rightleftharpoons 2 \text{HF}(g)$$
  - a. Without doing any calculations, determine whether or not this process is thermodynamically favored. Justify your answer.
  - b. Calculate the equilibrium constant,  $K_{\text{eq}}$ , at 25°C.
  - c. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.
- 7) For the reaction below  $\Delta H^\circ = -106.7$  kJ/mol and  $\Delta S^\circ = -142.2$  J/molK.
$$\text{C}_{(\text{graphite})} + 2 \text{Cl}_2(g) \rightleftharpoons \text{CCl}_4(g)$$
  - a. Calculate  $\Delta G^\circ$ .
  - b. Does the system contain mostly reactants or mostly products at equilibrium? Explain.
- 8) For the reaction below  $\Delta H^\circ = -508.3$  kJ/mol and  $\Delta S^\circ = -178$  J/molK.
$$2 \text{PCl}_3(g) + \text{O}_2(g) \rightleftharpoons 2 \text{POCl}_3(g)$$
  - a. Calculate  $\Delta G^\circ$ .
  - b. Is this process thermodynamically favored? Explain.
  - c. Find  $Q_p$  if the partial pressures are found to be:  $(P_{\text{PCl}_3}) = 1.14$  atm,  $(P_{\text{O}_2}) = 0.73$  atm, and  $(P_{\text{POCl}_3}) = 0.54$  atm.
  - d. Find  $K_{\text{eq}}$  for the reaction at 298 K.
  - e. In which direction will the reaction proceed? Justify your answer.

- 9) For the reaction below,  $\Delta H^\circ = 85 \text{ kJ/mol}$  and  $\Delta S^\circ = 198 \text{ J/molK}$ .

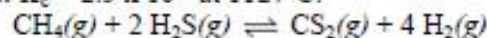


- Calculate  $\Delta G^\circ$ .
- Find  $Q_p$  if the partial pressures are found to be:  
( $P_{\text{N}_2\text{F}_4}$ ) = 0.94 atm, and ( $P_{\text{NF}_2}$ ) = 0.72 atm.

- 10) Find  $\Delta G^\circ_{700\text{K}}$  for the reaction below.  $K_p = 0.140$  at 700 K.



- 11) For the reaction below  $K_c = 2.5 \times 10^{-3}$  at  $1127^\circ\text{C}$ .



- Find  $K_p$ .
- Find  $\Delta G^\circ_{1400\text{K}}$  in kJ/mol.

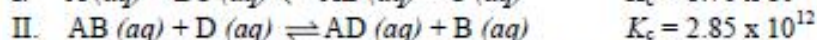
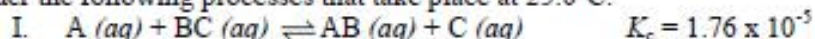
- 12) For a certain reaction  $K_p = 3.54$  at  $325^\circ\text{C}$ . Find  $\Delta G^\circ_{598\text{K}}$  in kJ/mol.

- 13) If  $\Delta H^\circ = -246 \text{ kJ}$  and  $\Delta S^\circ = +146 \text{ J/K}$  for a reaction, will  $K_{\text{eq}}$  be greater than 1, less than 1, or equal to 1? Provide justification for your answer without doing any calculation.

- 14) Find the equilibrium constant,  $K_p$ , for the following reaction at 298 K using the thermodynamic values from the appendix in your textbook.



- 15) Consider the following processes that take place at  $25.0^\circ\text{C}$ .



- Is process I. thermodynamically favored? Justify your answer.
- Is process II. thermodynamically favored? Justify your answer.
- Find the equilibrium constant,  $K_c$ , for the following process at  $25.0^\circ\text{C}$ .  
$$\text{A}(aq) + \text{BC}(aq) + \text{D}(aq) \rightleftharpoons \text{C}(aq) + \text{AD}(aq) + \text{B}(aq)$$
- Is the process in part c. thermodynamically favored? Justify your answer.
- Can non-thermodynamically favored processes become thermodynamically favored when they are coupled with other thermodynamically favored processes?