

**Equilibrium II**  
**Worksheet**

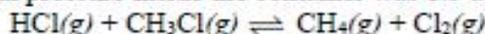
- 1) The equilibrium constant,  $K_c$ , is  $9.8 \times 10^5$  for  $\text{H}_2(\text{g}) + \text{S}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g})$ .
- Find the reaction quotient,  $Q_c$ , if  $[\text{H}_2] = 0.762 \text{ M}$  and  $[\text{H}_2\text{S}] = 0.483 \text{ M}$ .
  - Has the process established equilibrium? If not, in which direction will it proceed? Justify your answer.
- 2) The equilibrium constant,  $K_c$ , is 4.7 for  $\text{H}_2\text{O}(\text{g}) + \text{CH}_4(\text{g}) \rightleftharpoons 3 \text{H}_2(\text{g}) + \text{CO}(\text{g})$  at  $1127^\circ\text{C}$ .
- Find the reaction quotient,  $Q_c$ , when 0.20 mol  $\text{H}_2\text{O}(\text{g})$ , 0.50 mol  $\text{CH}_4(\text{g})$ , 1.7 mol  $\text{H}_2(\text{g})$ , and 0.60 mol  $\text{CO}(\text{g})$  are placed in a rigid 2.5 L container at  $1127^\circ\text{C}$ .
  - Has the process established equilibrium? If not, in which direction will it proceed? Justify your answer.
- 3) The equilibrium constant,  $K_p$ , is 0.140 for  $\text{ClF}_3(\text{g}) \rightleftharpoons \text{F}_2(\text{g}) + \text{ClF}(\text{g})$  at  $427^\circ\text{C}$ .
- Find the reaction quotient,  $Q_p$ , when the partial pressures are 0.632 atm for  $\text{ClF}_3$ , 0.025 atm for  $\text{F}_2$ , and 0.097 atm for  $\text{ClF}$ .
  - Will the partial pressure of  $\text{ClF}_3$  increase, decrease, or stay the same as the system approaches equilibrium? Justify your answer.
- 4) Suppose  $\text{NaOH}$  is added to the following system when it is at equilibrium.
- $$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$$
- In which direction will the reaction shift after the  $\text{NaOH}$  is added?
  - Will this stress increase or decrease the value of the reaction quotient,  $Q$ ? Justify your answer.
  - Will the rate of the forward reaction exceed the rate of the reverse reaction before equilibrium is re-established? Justify your answer.
  - When equilibrium is re-established will the rate of the forward reaction exceed the rate of the reverse reaction? Justify your answer.
- 5) Suppose additional  $\text{CO}(\text{g})$  is added to the following system when it is at equilibrium?  $\text{CO}(\text{g}) + \text{PbO}(\text{s}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{Pb}(\text{s})$
- In which direction will the reaction shift after the  $\text{CO}$  is added?
  - Will this stress increase or decrease the value of the reaction quotient,  $Q$ ? Justify your answer.
  - Will the rate of the forward reaction exceed the rate of the reverse reaction before equilibrium is re-established? Justify your answer.
  - When equilibrium is re-established will  $Q$  be greater than, equal to, or less than  $K$ ? Justify your answer.
- 6) Suppose  $\text{SO}_2$  is removed from the following system when it is at equilibrium.
- $$\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq})$$
- In which direction will the reaction shift after the  $\text{SO}_2$  is removed?

- b. Will the value of the reaction quotient,  $Q$ , change in response to this stress? Justify your answer.
- c. Will the value of the equilibrium constant,  $K_{eq}$ , change in response to this stress? Justify your answer.
- 7) Will the equilibrium below shift when the pressure is reduced? If so, in which direction will it shift?  $\text{Br}_2(g) + 3 \text{F}_2(g) \rightleftharpoons 2 \text{BrF}_3(g)$
- 8) In order to maximize the production of sulfur dioxide gas, a chemist suggested that they increase the pressure on the following system. Would this work? Justify your answer.  $2 \text{PbS}(g) + 3 \text{O}_2(g) \rightleftharpoons 2 \text{PbO}(s) + 2 \text{SO}_2(g)$ .
- 9) A chemical company was producing  $\text{Mo}(\text{CO})_5\text{P}(\text{CH}_3)_3$  through the following process.
- $$\text{Mo}(\text{CO})_5 + \text{P}(\text{CH}_3)_3 \rightleftharpoons \text{Mo}(\text{CO})_5\text{P}(\text{CH}_3)_3$$
- One of the chemists suggested that they should add  $\text{Mo}(\text{CO})_6$  to the system, as it would create the following reactions.
- $$\text{Mo}(\text{CO})_6 \rightleftharpoons \text{Mo}(\text{CO})_5 + \text{CO}$$
- Why would the chemist make this suggestion?
- 10) Will the equilibrium below shift when the pressure is reduced? If so, in which direction will it shift?  $\text{Cl}_2(g) + 2 \text{I}^-(aq) \rightleftharpoons 2 \text{Cl}^-(aq) + \text{I}_2(s)$
- 11) Will the equilibrium shift when the pressure acting on the following system is increased? If so, in which direction will it shift?  $\text{Br}_2(g) + \text{H}_2(g) \rightleftharpoons 2 \text{HBr}(g)$
- 12) In which direction will the equilibrium shift when heat is added to the following system?  $\text{CO}(g) + \text{NO}(g) \rightleftharpoons \text{CO}_2(g) + \frac{1}{2} \text{N}_2(g)$   $\Delta H_{rxn} = -373 \text{ kJ}$
- 13) In which direction will the equilibrium shift when heat is added to the following system?  $2 \text{N}_2\text{O}_5(s) \rightleftharpoons 4 \text{NO}(g) + 3 \text{O}_2(g)$   $\Delta H_{rxn} = +247.4 \text{ kJ}$
- 14) Will decreasing the temperature of the following system cause the ratio of  $[\text{CO}]/[\text{CO}_2]$  increase or decrease? Justify your answer.
- $$2 \text{CO}(g) + \text{O}_2(g) \rightleftharpoons 2 \text{CO}_2(g) \quad \Delta H_{rxn} = -566.0 \text{ kJ}$$
- 15)  $\text{NO}_2(g)$  is a reddish-brown color and  $\text{N}_2\text{O}_4(g)$  is colorless. Suppose the two gases establish the following equilibrium.
- $$\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g) \quad \Delta H^\circ = -57.2 \text{ kJ}$$
- If the temperature increased from  $25^\circ\text{C}$  to  $45^\circ\text{C}$ , and the volume remained the same, what would happen to the overall color of the gaseous system? Justify your answer.
- 16) What is the only thing that one can do to reduce the value of the equilibrium constant,  $K_{eq}$ , for the following system?
- $$2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \quad \Delta H_{rxn} = -198.4 \text{ kJ}$$
- 17) The value of  $K_{eq}$  for a certain reaction is 5.6 at 650 K and 1.2 at 125 K. Is the forward reaction endothermic or exothermic? Justify your answer.
- 18) Will the equilibrium below shift if distilled water is added to the system? If so, in which direction will it shift?  $\text{CH}_3\text{COOH}(aq) \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}^+(aq)$

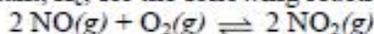
- 19) Gaseous HCl is added to a rigid vessel containing excess solid iodine at 25°C until the partial pressure of HCl reaches 1.47 atm. The following reaction brings the system to equilibrium.



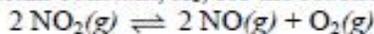
- Find the equilibrium partial pressures of all species at 25°C.
  - The temperature of the system changed, and the equilibrium constant,  $K_p$ , became  $8.39 \times 10^{-27}$ . Find the new partial pressures of all the species at equilibrium.
- 20) The equilibrium constant,  $K_p$ , is  $6.3 \times 10^{-5}$  at 1500 K for the reaction represented below. A chemist mixed 55%  $\text{CH}_3\text{Cl}(g)$  and 45%  $\text{HCl}(g)$  by moles into a rigid container until the total pressure inside the container was 1.5 atm at 1500 K.



- Find the initial partial pressures of each gas.
  - Find the equilibrium partial pressures of each gas at 1500 K.
  - The temperature of the system changed, and the equilibrium constant,  $K_p$ , became  $4.7 \times 10^{-10}$ . Find the new partial pressures of all gaseous species at equilibrium.
- 21) The equilibrium constant,  $K_c$ , for the following reaction is  $6.44 \times 10^5$  at 230°C.



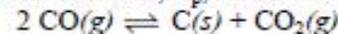
Calculate the equilibrium constant,  $K_c$ , for the reaction below at 230°C.



- 22) The equilibrium constant,  $K_p$ , for the following reaction is  $1.3 \times 10^{14}$  at 850°C.



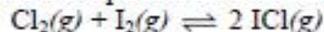
Calculate the equilibrium constant,  $K_p$ , for the reaction below at 850°C.



- 23) If the equilibrium constant,  $K_p$ , is 167 for  $\text{COCl}_2(g) \rightleftharpoons \text{CO}(g) + \text{Cl}_2(g)$  and the equilibrium constant,  $K_p$ , is  $8.8 \times 10^{-8}$  for  $\text{CO}(g) \rightleftharpoons \frac{1}{2} \text{C}(s) + \frac{1}{2} \text{CO}_2(g)$  at 850°C, find  $K_p$  for  $\text{COCl}_2(g) \rightleftharpoons \text{Cl}_2(g) + \frac{1}{2} \text{CO}_2(g) + \frac{1}{2} \text{C}(s)$  at 850°C.

- 24) The equilibrium constant,  $K_c^i$ , is  $3.2 \times 10^{-34}$  for  $2\text{HCl}(g) \rightleftharpoons \text{H}_2(g) + \text{Cl}_2(g)$  and the equilibrium constant,  $K_c^{ii}$ , is 0.10 for  $2 \text{ICl}(g) \rightleftharpoons \text{Cl}_2(g) + \text{I}_2(g)$  at 25°C.

- Calculate the equilibrium constant,  $K_c$ , for the reaction below at 25°C.



- Calculate the equilibrium constant,  $K_c$ , for the reaction below at 25°C.

