

Equilibrium II
Worksheet

- 1) The equilibrium constant, K_c , is 9.8×10^5 for $\text{H}_2(g) + \text{S}(s) \rightleftharpoons \text{H}_2\text{S}(g)$.
 - a. Find the reaction quotient, Q_c , if $[\text{H}_2] = 0.762 \text{ M}$ and $[\text{H}_2\text{S}] = 0.483 \text{ M}$.
 - b. 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 $\text{H}_2\text{O}(g) + \text{CH}_4(g) \rightleftharpoons 3 \text{ H}_2(g) + \text{CO}(g)$ at 1127°C .
 - a. Find the reaction quotient, Q_c , when 0.20 mol $\text{H}_2\text{O}(g)$, 0.50 mol $\text{CH}_4(g)$, 1.7 mol $\text{H}_2(g)$, and 0.60 mol $\text{CO}(g)$ are placed in a rigid 2.5 L container at 1127°C .
 - b. 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 $\text{ClF}_3(g) \rightleftharpoons \text{F}_2(g) + \text{ClF}(g)$ at 427°C .
 - a. Find the reaction quotient, Q_p , when the partial pressures are 0.632 atm for ClF_3 , 0.025 atm for F_2 , and 0.097 atm for ClF .
 - b. Will the partial pressure of ClF_3 increase, decrease, or stay the same as the system approaches equilibrium? Justify your answer.

- 4) Suppose NaOH is added to the following system when it is at equilibrium.
$$\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$$
 - a. In which direction will the reaction shift after the NaOH is added?
 - b. Will this stress increase or decrease the value of the reaction quotient, Q ? Justify your answer.
 - c. Will the rate of the forward reaction exceed the rate of the reverse reaction before equilibrium is re-established? Justify your answer.
 - d. 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 $\text{CO}(g)$ is added to the following system when it is at equilibrium? $\text{CO}(g) + \text{PbO}(s) \rightleftharpoons \text{CO}_2(g) + \text{Pb}(s)$
 - a. In which direction will the reaction shift after the CO is added?
 - b. Will this stress increase or decrease the value of the reaction quotient, Q ? Justify your answer.
 - c. Will the rate of the forward reaction exceed the rate of the reverse reaction before equilibrium is re-established? Justify your answer.
 - d. When equilibrium is re-established will Q be greater than, equal to, or less than K ? Justify your answer.

- 6) Suppose SO_2 is removed from the following system when it is at equilibrium.
$$\text{SO}_2(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{SO}_3(aq)$$
 - a. In which direction will the reaction shift after the SO_2 is removed?

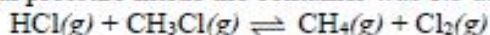
- b. Will the value of the reaction quotient, Q , change in response to this stress? Justify your answer.
- c. Will the value of the equilibrium constant, K_{eq} , change in response to this stress? Justify your answer.
- 7) Will the equilibrium below shift when the pressure is reduced? If so, in which 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 $\text{Mo(CO)}_5\text{P(CH}_3)_3$ through the following process.
- $$\text{Mo(CO)}_5 + \text{P(CH}_3)_3 \rightleftharpoons \text{Mo(CO)}_5\text{P(CH}_3)_3$$
- One of the chemists suggested that they should add Mo(CO)_6 to the system, as it would create the following reactions.
- $$\text{Mo(CO)}_6 \rightleftharpoons \text{Mo(CO)}_5 + \text{CO}$$
- 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? $\text{CO}(g) + \text{NO}(g) \rightleftharpoons \text{CO}_2(g) + \frac{1}{2} \text{N}_2(g)$ $\Delta H_{\text{rxn}} = -373 \text{ kJ}$
- 13) In which direction will the equilibrium shift when heat is added to the following system? $2 \text{N}_2\text{O}_5(s) \rightleftharpoons 4 \text{NO}(g) + 3 \text{O}_2(g)$ $\Delta H_{\text{rxn}} = +247.4 \text{ kJ}$
- 14) Will decreasing the temperature of the following system cause the ratio of $[\text{CO}]/[\text{CO}_2]$ increase or decrease? Justify your answer.
- $$2 \text{CO}(g) + \text{O}_2(g) \rightleftharpoons 2 \text{CO}_2(g) \quad \Delta H_{\text{rxn}} = -566.0 \text{ kJ}$$
- 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°C to 45°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?
- $$2 \text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{SO}_3(g) \quad \Delta H_{\text{rxn}} = -198.4 \text{ kJ}$$
- 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.



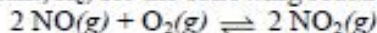
- Find the equilibrium partial pressures of all species at 25°C.
- The temperature of the system changed, and the equilibrium constant, K_p , became 8.39×10^{-27} . Find the new partial pressures of all the species at equilibrium.

- 20) The equilibrium constant, K_p , is 6.3×10^{-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.

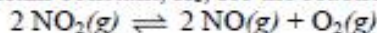


- Find the initial partial pressures of each gas.
- Find the equilibrium partial pressures of each gas at 1500 K.
- The temperature of the system changed, and the equilibrium constant, K_p , became 4.7×10^{-10} . Find the new partial pressures of all gaseous species at equilibrium.

- 21) The equilibrium constant, K_c , for the following reaction is 6.44×10^5 at 230°C.



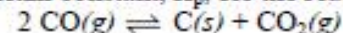
Calculate the equilibrium constant, K_c , for the reaction below at 230°C.



- 22) The equilibrium constant, K_p , for the following reaction is 1.3×10^{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 8.8×10^{-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 3.2×10^{-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.

$$\text{Cl}_2(g) + \text{I}_2(g) \rightleftharpoons 2 \text{ICl}(g)$$
- Calculate the equilibrium constant, K_c , for the reaction below at 25°C.

$$2 \text{HCl}(g) + \text{I}_2(g) \rightleftharpoons 2 \text{ICl}(g) + \text{H}_2(g)$$