16 • Chemical Equilibrium

1. Consider the reaction system, 
CoO(s) + H₂(g) ⇌ Co(s) + H₂O(g).

The equilibrium constant expression is
a) \([\text{CoO}] [\text{H}_2] \)  
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{CoO}][\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{CoO}][\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}}\)

b) \([\text{CoO}] [\text{H}_2\text{O}] \) 
\(\frac{[\text{Co}][\text{H}_2]}{[\text{CoO}][\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}] [\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}}\)

c) \([\text{Co}][\text{H}_2\text{O}]\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}][\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}][\text{H}_2]}\) 
\(\frac{[\text{Co}][\text{H}_2\text{O}]}{[\text{Co}}\)

d) \([\text{H}_2\text{O}] \) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}][\text{H}_2]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}][\text{H}_2]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}][\text{H}_2]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}][\text{H}_2]}{[\text{H}_2]}\)

e) \([\text{H}_2\text{O}] \) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\) 
\(\frac{[\text{H}_2\text{O}]}{[\text{H}_2]}\)

2. Given the equilibrium,
2SO₂(g) + O₂(g) ⇌ 2SO₃(g), if this equilibrium is established by beginning with equal number of moles of SO₂ and O₂ in a 1.0 Liter bulb, then the following must be true at equilibrium:

a) \([\text{SO}_2] = [\text{SO}_3]\) 
\(2[\text{SO}_2] = 2[\text{SO}_3]\) 
\(2[\text{SO}_2] = [\text{SO}_3]\)

b) \([\text{SO}_2] = [\text{O}_2]\) 
\(2[\text{SO}_2] = [\text{SO}_3]\) 
\([\text{SO}_2] = [\text{SO}_3]\)

c) \([\text{SO}_2] = [\text{O}_2]\) 
\([\text{SO}_2] = [\text{O}_2]\) 
\([\text{SO}_2] = [\text{O}_2]\)

Questions 3 & 4 refer to the following:

At a given temperature, 0.300 mole NO, 0.200 mol Cl₂ and 0.500 mol ClNO were placed in a 25.0 Liter container. The following equilibrium is established: 2ClNO(g) ⇌ 2NO(g) + Cl₂(g)

3. At equilibrium, 0.600 mol of ClNO was present. The number of moles of Cl₂ present at equilibrium is

a) 0.050 
\(\text{d) 0.200}\) 
\(\text{b) 0.100}\) 
\(\text{e) 0.250}\) 
\(\text{c) 0.150}\)

4. The equilibrium constant, \(K_c\), is:

a) \(4.45 \times 10^{-4}\) 
\(b) 6.67 \times 10^{-4}\) 
\(c) 0.111\) 
\(d) 0.167\) 
\(e) 1500\)

5. At 985°C, the equilibrium constant for the reaction, 
\(\text{H}_2(g) + \text{CO}_2(g) \rightleftharpoons \text{H}_2\text{O}(g) + \text{CO}(g)\)

is 1.63. What is the equilibrium constant for the reverse reaction?

a) 1.63 
\(\text{d) 0.613}\) 
\(\text{b) 0.815}\) 
\(\text{e) 1.00}\) 
\(\text{c) 2.66}\)

6. What is the relationship between \(K_p\) and \(K_c\) for the reaction, \(2\text{ICl}(g) \rightleftharpoons \text{I}_2(g) + \text{Cl}_2(g)\)?

a) \(K_p = K_c(RT)^{-1}\) 
\(\text{d) } K_p = K_c\) 
\(\text{b) } K_p = K_c(RT)\) 
\(\text{e) } K_p = K_c(2RT)\) 
\(\text{c) } K_p = K_c(RT)^2\)

7. For the reaction \(2\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g)\), \(K_p\) at 25°C is 7.3, when all partial pressures are expressed in atmospheres. What is \(K_c\) for this reaction? \([R=0.0821 \text{ L} \cdot \text{atm}^{-1} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}]\)

a) 4270 
\(\text{d) 179}\) 
\(\text{b) 0.0119}\) 
\(\text{e) 2.06}\) 
\(\text{c) 0.291}\)
8. 0.200 mol NO is placed in a one liter flask at 2273 K. After equilibrium is attained, 0.0863 mol N₂ and 0.0863 mol O₂ are present. What is K_c for this reaction?

\[ 2\text{NO(g)} \rightleftharpoons \text{N}_2\text{(g)} + \text{O}_2\text{(g)} \]

\[ \text{a) 9.92} \quad \text{d) 39.7} \]

\[ \text{b) 3.15} \quad \text{e) 0.576} \]

\[ \text{c) 0.0372} \]

9. \[ \text{N}_2\text{O}_4\text{(g)} \rightleftharpoons 2\text{NO}_2\text{(g)} \]

At 25°C, 0.11 mole of N₂O₄ reacts to form 0.10 mol of N₂O₄ and 0.02 mole of NO₂. At 90°C, 0.11 mole of N₂O₄ forms 0.050 mole of N₂O₄ and 0.12 mole of NO₂. From these data we can conclude

\[ \text{a) } \text{N}_2\text{O}_4 \text{ molecules react by a second order rate law.} \]

\[ \text{b) } \text{N}_2\text{O}_4 \text{ molecules react by a first order rate law.} \]

\[ \text{c) } \text{the reaction is exothermic.} \]

\[ \text{d) } \text{N}_2\text{O}_4 \text{ molecules react faster at 25°C than at 90°C.} \]

\[ \text{e) } \text{the equilibrium constant for the reaction above increases with an increase in temperature.} \]

10. For the equilibrium system

\[ \text{H}_2\text{O(g)} + \text{CO(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{CO}_2\text{(g)} \]

\[ \Delta H = -42 \text{ kJ/mol} \]

K_c equals 0.62 at 1260 K. If 0.10 mole each of H₂O, CO, H₂ and CO₂ (each at 1260 K) were placed in a 1.0-Liter flask at 1260 K, when the system came to equilibrium...

<table>
<thead>
<tr>
<th>The temperature would</th>
<th>The mass of CO would</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) decrease</td>
<td>increase</td>
</tr>
<tr>
<td>b) decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>c) remain constant</td>
<td>increase</td>
</tr>
<tr>
<td>d) increase</td>
<td>decrease</td>
</tr>
<tr>
<td>e) increase</td>
<td>increase</td>
</tr>
</tbody>
</table>

11. For the reaction system,

\[ \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)} + \text{heat} \]

the conditions that would favor maximum conversion of the reactants to products would be

\[ \text{a) high temperature and high pressure} \]

\[ \text{b) high temperature, pressure unimportant} \]

\[ \text{c) high temperature and low pressure} \]

\[ \text{d) low temperature and high pressure} \]

\[ \text{e) low temperature and low pressure} \]

12. Solid HgO, liquid Hg, and gaseous O₂ are placed in a glass bulb and are allowed to reach equilibrium at a given temperature.

\[ 2\text{HgO(s)} \rightleftharpoons 2\text{Hg(l)} + \text{O}_2\text{(g)} \quad \Delta H = +43.4 \text{ kcal} \]

The mass of HgO in the bulb could be increased by

\[ \text{a) adding more Hg.} \]

\[ \text{b) removing some O}_2. \]

\[ \text{c) reducing the volume of the bulb.} \]

\[ \text{d) increasing the temperature.} \]

\[ \text{e) removing some Hg.} \]

**Answers:** (Please use **CAPITAL** letters)

1. 7. 7. 8. 9. 10. 11. 12.