Chemistry 12

Tutorial 5 - Solutions
The Equilibrium Constant (K_{eq})

Answer to question 1 on page 2 of Tutorial 5

1. With this in mind, see if you can write the K_{eq} expression for the following reaction:

$$2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$$

$$K_{eq} = \frac{[N_2]\,[H_2]^3}{[NH_3]^2}$$

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Answer to question 2 on page 3 of Tutorial 5.

2. Write the K_{eq} expression for the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

$$K_{eq} = \frac{[NH_3]^2}{[N_2]\,[H_2]^3}$$

Notice that this time the $[NH_3]^2$ is on top and the $[N_2]\,[H_2]^3$ is on the bottom, because in the balanced equation, NH_3 was on the right side and N_2 and H_2 were on the left side.

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Answer to question 3 on page of Tutorial 5

3. Write the K_{eq} expression for the following reaction:

$$CaCO_{3(s)} + 2HF_{(g)} \rightleftarrows CaF_{2(s)} + H_2O_{(l)} + CO_{2(g)}$$

$$K_{eq} = \frac{[CO_2]}{[HF]^2}$$

Notice that the solids and liquids are completely left out of the K_{eq} expression.

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Answer to question 4 on page 6 of Tutorial 5

4. For the reaction: $Cu(OH)_{2(s)} \rightleftarrows Cu^{2+}_{(aq)} + 2OH^-_{(aq)}$ $K_{eq} = 1.6 \times 10^{-19}$

Describe the extent of the reaction and the relative amounts of reactant and product at equilibrium.

The value of K_{eq} is <u>very small.</u> This means that this reaction has proceeded to an <u>extremely small extent</u> at equilibrium. At equilibrium <u>almost all</u> of the $Cu(OH)_2(s)$ would remain and there would be <u>very little</u> $Cu^{2+}_{(aq)}$ or $OH^-_{(aq)}$ formed.

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Answers to question 5 on page 8-9 of Tutorial 5

5. Given the equation for an ***exothermic*** reaction:

$$C + D \rightleftarrows E + heat$$

a) Write the K_{eq} expression for this reaction:

$$K_{eq} = \frac{[E]}{[C]\,[D]}$$

b) If the *temperature* of this exothermic reaction is ***increased***, the equilibrium will shift to the ___**left**_____.(The heat term is on the right.)

c) The shift will make [E] __**smaller**__, and [C] and [D] ___**larger**_____ than they were before.

d) Since the numerator is _____**smaller**_____ and the denominator is _____**larger**_____, the value of the K_{eq} will be____ **smaller** ___ than it was before.

$$K_{eq} = \frac{[E]}{[C]\,[D]}$$

e) If the temperature of this system is ***decreased***, the equilibrium will shift to the

$$C + D \rightleftarrows E + heat$$

_____**right**_____, and the value of K_{eq} will ___**increase**_____

f). Fill in the following blanks:

When the ***temperature is increased*** in an ***exothermic*** reaction, the equilibrium

Will ***shift to the __left___*** and the ***value of K_{eq} will ___decrease___***.

and

When the ***temperature is decreased*** in an ***exothermic*** reaction, the equilibrium

will ***shift to the __right___*** and the ***value of K_{eq} will___ increase_____***

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Answer to question 6 on page 9 of Tutorial 5

6. The reaction: $X + Y \rightleftarrows Z$ has a $K_{eq} = 235$ at 100°C.

When the temperature is raised to 200°C, the value for $K_{eq} = 208$

Is this reaction endothermic or exothermic? **exothermic**

Explain your answer. **When the temperature is increased (heat is added), the value for K_{eq} decreases (from 235 down to 208). This can be explained by saying that the reaction is exothermic (the heat term is on the right)**

$$X + Y \rightleftarrows Z + \text{heat}$$

As heat is added, this equilibrium would shift to the left, [X] and [Y] would get larger and [Z] would get smaller.

Therefore the value of the K_{eq} would get smaller:

$$K_{eq} = \frac{[Z]}{[X]\,[Y]}$$

the *numerator is smaller* and the *denominator is larger*. This makes the value of K_{eq} ***smaller***.

So this reaction is ***exothermic***. This is consistent with the fact that the *value* for K_{eq} *decreases* when the *temperature is increased*.

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Answers to Self-Test starting on page 12 of Tutorial 5

Self-Test on Tutorial 5

1. Write the ***Equilibrium Constant Expression*** for each of the following reactions. (Be careful of the phases!)

a) $A_{(s)} + B_{(g)} \rightleftarrows 2C_{(g)}$ $\quad K_{eq} = \dfrac{[C]^2}{[B]}$

b) $COCl_{2(g)} \rightleftarrows CO_{(g)} + Cl_{2(g)}$ $\quad K_{eq} = \dfrac{[CO]\,[Cl_2]}{[COCl_2]}$

c) $Zn_{(s)} + 2HCl_{(aq)} \rightleftarrows H_{2(g)} + ZnCl_{2(aq)}$ $\quad K_{eq} = \dfrac{[H_2]\,[ZnCl_2]}{[HCl]^2}$

2. A _____**large**_____ value for K_{eq} means that a reaction has gone close to completion.

3. A _____**small**_____ value for K_{eq} means that a reaction has **not** occurred to much of an extent.

4. A value of around 1.0 for K_{eq} means **there is roughly the same amount of products as reactants. (Depending on the coefficients - the exponents may complicate things)**

5. Given the equilibrium equation:

$2NO_{2(g)} \rightleftarrows N_2O_{4(g)} + \text{heat}$ $K_{eq} = 1.20$ at 55°C

What will happen to the value of K_{eq} if the temperature is increased? **decrease**

Explain why **Since the reaction is exothermic (heat term is on the right), an increase in temperature will shift the equilibrium to the left. This will decrease the numerator and increase the denominator, thus the value of K_{eq} will decrease.**

$$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} < 1.20$$

6. For the reaction: $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$ $K_{eq} = 2.24$ at 227°C

$K_{eq} = 33.3$ at 487°C

Is this reaction endothermic or exothermic? **endothermic**

Explain your answer . **The value of K_{eq} increase when the temperature increases. This will only happen if the heat term is on the left (endothermic).**

$$PCl_{5(g)} + \text{heat} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

When the temperature is increased, this equilibrium will shift to the right, increasing $[PCl_3]$ and $[Cl_2]$ while decreasing $[PCl_5]$. This would increase the value of K_{eq} .

$$\mathbf{K_{eq} = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}}$$

7. If the t*emperature remains constant* in an equilibrium:

a) Will changing the ***concentration*** of one of the substances change the value of K_{eq} ?

Answer **no!**

b) Will changing the ***total pressure*** of the system change the value of K_{eq} ?

Answer **no!**

c) Will changing the ***total volume*** of the system change the value of K_{eq} ?

Answer ____**no!**_____

d) Will adding a ***catalyst*** change the value of K_{eq} ?

Answer ___**no!**_____

8. The K_{eq} for the reaction: $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$ is 85 at 25°C

Determine the value of K_{eq} for the reaction: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ at 25°C

Since the second reaction is just the reverse of the first reaction, it's K_{eq} expression will just be the inverse of the K_{eq} expression for the first reaction.

$$K_{eq\ (1)} = \frac{[H_2]\,[I_2]}{[HI]^2} = 85 \qquad K_{eq\ (2)} = \frac{[HI]^2}{[H_2]\,[I_2]} = \frac{1}{85} = 0.01176$$

Answer __**0.012**____

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This is the end of Tutorial 5. If you have any questions make sure you see your teacher!