Chapter 13 Part 2

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Relating K and Chemical Equations

- If a chemical equation is modified in some way, the equilibrium constant must be changed to reflect the modification

Relating K and Chemical Equations

1. If you reverse the equation, invert the equilibrium constant

Original Equation

$$A + 2\,B \leftrightharpoons 3\,C \qquad K_{forward} = \frac{[C]^3}{[A][B]^2}$$

New Equation

$$3\,C \leftrightharpoons A + 2\,B \qquad K_{reverse} = \frac{[A][B]^2}{[C]^3} = \frac{1}{K_{forward}} = (K_{forward})^{-1}$$

Relating K and Chemical Equations

2. If you multiply the coefficients in the equation by a factor, raise the equilibrium constant to the same factor

Original Equation

$$\mathrm{A} + 2\,\mathrm{B} \leftrightharpoons 3\,\mathrm{C} \qquad \mathrm{K} = \frac{[\mathrm{C}]^3}{[\mathrm{A}][\mathrm{B}]^2}$$

New Equation

$$n\,\mathrm{A} + 2n\,\mathrm{B} \leftrightharpoons 3n\,\mathrm{C} \qquad \mathrm{K}' = \frac{[\mathrm{C}]^{3n}}{[\mathrm{A}]^n[\mathrm{B}]^{2n}} = \left(\frac{[\mathrm{C}]^3}{[\mathrm{A}][\mathrm{B}]^2}\right)^n = \mathrm{K}^n$$

Relating K and Chemical Equations

3. If you add two or more individual chemical equations, multiply the corresponding equilibrium constants by each other to obtain the overall equilibrium constant.

Original Equations

$$A \leftrightharpoons \cancel{2\,B} \qquad K_1 = \frac{[B]^2}{[A]}$$

$$\cancel{2\,B} \leftrightharpoons 3\,C \qquad K_2 = \frac{[C]^3}{[B]^2}$$

New Equation

$$A \leftrightharpoons 3\,C \qquad K_{overall} = K_1 \times K_2 = \frac{[C]^3}{[A]}$$

Relating K and Chemical Equations

Consider the following chemical equation and equilibrium constant for the synthesis of ammonia at 25°C:

$$N_2(g) + 3\,H_2(g) \leftrightharpoons 2\,NH_3(g) \quad K = 3.7 \times 10^8$$

Compute the equilibrium constant for the following reaction at 25°C.

$$NH_3(g) \leftrightharpoons \frac{1}{2}\,N_2(g) + \frac{3}{2}\,H_2(g)$$

Relating K and Chemical Equations

Predict the equilibrium constant for the first reaction given the equilibrium constants for the second and third reactions:

$$CO_2(g) + 3\,H_2(g) \leftrightharpoons CH_3OH(g) + H_2O(g) \quad K_1 = ?$$

$$CO(g) + H_2O(g) \leftrightharpoons CO_2(g) + H_2(g) \quad K_2 = 1.0 \times 10^5$$

$$CO(g) + 2\,H_2(g) \leftrightharpoons CH_3OH(g) \quad K_3 = 1.4 \times 10^7$$

Relating K and Chemical Equations

How should the two equilibrium constants K_1 and K_2 be mathematically combined to give the overall equilibrium constant for the reaction $2\ X \rightleftharpoons Z$?

$$2\ W + X \rightleftharpoons Y \qquad K_1$$
$$X + Y \rightleftharpoons 2\ W + Z \qquad K_2$$

A. $(K_1) + (K_2)$

B. $(K_1) - (K_2)$

C. $(K_1)(K_2)$

D. $(K_1)/(K_2)$

Le Chatelier's Principle

- When a system at equilibrium is disturbed, it returns to equilibrium by counteracting the disturbance.

Changing the concentration

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

Changing the concentration

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

Which direction will the equilibrium shift in order to reestablish equilibrium if

- the concentration of H_2 is increased?

Changing the concentration

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

Which direction will the equilibrium shift in order to reestablish equilibrium if

- the concentration of I_2 is decreased?

Changing the concentration

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

Which direction will the equilibrium shift in order to reestablish equilibrium if

- the concentration of HI is decreased?

Changing the concentration

Determine the direction in which this reaction shifts after the following changes are made to the system.

$$2\ H_2S(g) \rightleftharpoons 2\ H_2(g) + S_2(g)$$

A. increasing the concentration of H_2S
B. increasing the concentration of H_2
C. removing S_2 from the system

Changing the concentration

- Changing the concentrations of solids and pure liquids do not apply to Le Chatelier's principle as they do not affect the equilibrium constant.

Changing the temperature

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g) \quad \Delta H = -9.4\ kJ$$

Is this reaction endothermic or exothermic?

Does this mean that energy is released or absorbed?

Changing the temperature

This means that we can write the equation with energy as a product

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g) + \text{energy}$$

Changing the temperature

This means that we can write the equation with energy as a product

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g) + \text{energy}$$

Changing the temperature will now just be like changing the concentration

- Raising the temperature is increasing the concentration of energy
- Lowering the temperature is decreasing the concentration of energy

Changing the temperature

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g) \quad \Delta H = -9.4\ kJ$$

What direction will the equilibrium shift if the temperature is increased?

Changing the temperature

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g) \quad \Delta H = 57.20\ kJ$$

What direction will the equilibrium shift if the temperature is increased?

Changing the temperature

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g) \quad \Delta H = 57.20\ kJ$$

What direction will the equilibrium shift if the temperature is decreased?

Changing the pressure

Changing the pressure only has a measureable effect on gaseous systems

Changing the pressure (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

How many moles are on the products side?

Changing the pressure (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

Would increasing the pressure of the system put more strain on a reaction making something with more moles or less moles?

Changing the pressure (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

Which direction will the equilibrium shift upon increasing the pressure?

Changing the pressure (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

Which direction will the equilibrium shift upon decreasing the pressure?

Changing the volume (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

Which direction will the equilibrium shift upon increasing the volume of the container?

Changing the volume (of a gaseous system)

The equation for a system at equilibrium is:

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)$$

Which direction will the equilibrium shift upon decreasing the volume of the container?

Changing volume and pressure

Determine the direction in which the equilibrium position of this reaction, occurring in a sealed container with variable volume, shifts after the changes below.

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$$

A. The volume of the container is decreased.

B. The volume of the container is increased.

C. The pressure of the container is increased.

Adding Catalysts

Does change

- The rate of the forward and reverse reaction (The system will reach equilibrium more quickly)

Doesn't change

- The value of the equilibrium constant
- Equilibrium concentrations

Adding a catalyst

The equation for a system at equilibrium is:

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

Which direction will the equilibrium shift upon adding a catalyst?

Le Chatelier's Principle

Which change will cause more CO_2 to form in a closed container? $\Delta H = 136$ kJ

$$2\ NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

A. adding $H_2O(g)$
B. removing $NaHCO_3(s)$
C. removing $Na_2CO_3(s)$
D. increasing the pressure
E. heating the container

Le Chatelier's Principle

Which change will shift this exothermic reaction to the right?

$$X(g) + 2\,Y(g) \rightleftharpoons XY_2(g)$$

A. adding argon and holding the container volume constant
B. adding a catalyst
C. removing products
D. removing reactants
E. heating the container