Lesson Description

In this lesson we:

- Discuss Le Chatelier’s Principle
- Discuss application of Le Chatelier’s Principle

Summary

Le Chatelier’s Principle

If the equilibrium in an isolated system is disturbed by changing one of the equilibrium conditions (temperature, concentration or pressure), the system reacts by counteracting the change and reaching a new equilibrium

Factors that influence chemical equilibrium

Concentration (only gases and solutions)

- Increase the concentration of reactants – the forward reaction is favoured
- Increase the concentration of products – the reverse reaction is favoured
- Decrease the concentration of reactants – the reverse reaction is favoured
- Decrease the concentration of products – the forward reaction is favoured

Pressure (only if there is at least one gas in the system)

- Increase the pressure of the system – the reaction which favours producing the least number of moles of gas is favoured
- Decrease the pressure of the system - the reaction which favours producing the most number of moles of gas is favoured

Temperature (affects the $K_c$ value)

- Increase temperature – increase rate of both reactions but the endothermic reaction is favoured
- Decrease temperature – decrease rate of both reactions but the exothermic reaction is favoured.

When answering questions consider the following:

- What is disturbing the equilibrium?
- How will the system counteract the disturbance?
- Which reaction is favoured?
- What changes will occur in the concentration of reactants and products?
- What is the effect on the $K_c$ value?
Test Yourself

Select the most correct answer from the options given. Write down only the correct letter.

Question 1

The following chemical equilibrium is established at a constant temperature in a closed container:

\[ 4\text{NH}_3(g) + 5\text{O}_2(g) \rightleftharpoons 4\text{NO}(g) + 6\text{H}_2\text{O}(g) \quad (\Delta H < 0) \]

The highest percentage yield of nitrogen oxide can be brought about by the following simultaneous changes in pressure and temperature.

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>B. Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>C. Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>D. Increase</td>
<td>decrease</td>
</tr>
</tbody>
</table>

Question 2

The following chemical equilibrium is established at 30°C.

\[ \text{NaNO}_3(aq) \rightleftharpoons \text{Na}^+(aq) + \text{NO}_3^-(aq) \]

A few drops of concentrated nitric acid are added to the above equilibrium mixture without significantly changing the volume or temperature of the mixture. Which of the following combinations best describes the possible change in equilibrium?

<table>
<thead>
<tr>
<th>Equilibrium</th>
<th>[products]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Reverse reaction is favoured</td>
<td>Decrease</td>
</tr>
<tr>
<td>B. Reverse reaction is favoured</td>
<td>Remain the same</td>
</tr>
<tr>
<td>C. No change</td>
<td>Remain the same</td>
</tr>
<tr>
<td>D. Reverse reaction is favoured</td>
<td>Increase</td>
</tr>
</tbody>
</table>

Question 3

Consider the following reaction having reached equilibrium at a constant high temperature in a closed container.

\[ \text{C}(s) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + \text{H}_2(g) \quad (\Delta H > 0) \]

The pressure on the system is then increased by decreasing the volume of the container. When a new equilibrium is reached at the same temperature it is found that the amount and the concentration of the CO has change as follows...
<table>
<thead>
<tr>
<th>Amount of CO</th>
<th>Concentration of CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>B. Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>C. Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>D. Decreases</td>
<td>Decreases</td>
</tr>
</tbody>
</table>

**Question 4**

Consider the following reaction which has attained equilibrium at a temperature of 448°C:

\[ \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI}(g) \quad (\Delta H < 0) \]

Which of the following changes will **increase** the concentration of HI at equilibrium?

- I. Increasing the pressure by reducing the volume
- II. Decreasing the temperature
- III. Adding a catalyst

A. Only I  
B. Only II  
C. I and II only  
D. II and III only  

**Question 5**

Initially, a certain amount of \(\text{ICl}_2(g)\) is sealed in an empty flask at a certain temperature. The reaction that takes place is:

\[2\text{ICl}_2(g) \rightleftharpoons \text{I}_2(g) + \text{Cl}_2(g)\]

Which of the following statements describe(s) the change(s) occurring as the system proceeds towards equilibrium?

- (i) The rate of the reverse reaction increases  
- (ii) The concentration of the \(\text{ICl}_2(g)\) increases  
- (iii) The concentration of the \(\text{Cl}_2(g)\) increases

A. (i) only  
B. (ii) only  
C. (i) and (iii) only  
D. (ii) and (iii) only

**Improve your skills**

**Question 1**

*(Adapted from Cape Province Paper 2 HG 1995)*

Hydrogen and oxygen are enclosed together in a 200 cm\(^3\) container at a temperature of 118°C. In the course of time the following chemical equilibrium occurs in the container:

\[2\text{H}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{H}_2\text{O}(g) \quad (\Delta H = -484 \text{ kJ})\]

In the table below possible changes to the equilibrium conditions are proposed, as well those aspects on which the changes can have an effect. (Write only NO EFFECT, INCREASES or DECREASES)
<table>
<thead>
<tr>
<th>Change</th>
<th>Effect on quantity of $O_2$</th>
<th>Effect on $K_c$ value</th>
<th>Effect on value of $\Delta H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure in container decreases at constant temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water vapour is removed from the container</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature changes to 105°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A catalyst is added</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 2**

*(Adapted from Natal Paper 2 1995)*

Consider the following dynamic equilibrium:

$$2CH_4(g) + O_2(g) \rightleftharpoons 2CO(g) + 4H_2(g)$$

2.1. Name the gas $CH_4$

2.2. What is meant by the term ‘dynamic’ equilibrium’ when used in this context?

The $K_c$ value or equilibrium constant for this reaction is reduced by increasing the temperature.

2.3. Is the forward reaction exothermic or endothermic? Explain your answer

2.4. How will the concentration of $H_2$ be affected if:
   2.4.1. CO is removed from the system?
   2.4.2. the volume of the reaction vessel is reduced?

**Question 3**

*(Adapted from DoE Exemplar Paper 2 2014)*

A sample of $N_2O_4$ gas is sealed in a container and heated. The $N_2O_4$ gas decomposes to $NO_2$ and the reaction reaches equilibrium according to the following balanced equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H > 0$$

The graph below shows how the concentrations of the two gases change as a result of changes made to the reaction conditions.

![Graph showing concentration change over time](image-url)
3.1. Define the term *chemical equilibrium*

3.2. How does the rate of the forward reaction compare to that of the reverse reaction at each of the following times? Only write down HIGHER THAN, LOWER THAN or EQUAL TO

3.2.1. \( t_1 \)
3.2.2. \( t_2 \)

3.3. What change was made to the reaction conditions at each of the following times? In both instances, the equilibrium constant for the reaction did not change.

3.3.1. \( t_3 \)
3.3.2. \( t_4 \)

3.4. How will an increase in temperature influence the yield of \( \text{NO}_2 \) (g)? Write down INCREASES, DECREASE or REMAINS THE SAME. Use Le Chatelier’s principle to explain the answer.