# Higher Chemistry

## Topic 3: Industrial Processes & Equilibrium

### Study Guide

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#### Lesson 3.7

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### Home Practice

- **A Score**: / 10
- **B Score**: / 10
- **C Score**: / 10
- **D Score**: / 10
**Chemical Equilibrium**

A chemical reaction that goes to completion is said to be at equilibrium. The forward reaction is balanced by the reverse reaction, and the concentrations of the reactants and products remain constant. The equilibrium constant, $K$, is given by:

$$K = \frac{[C]^a [B]^b}{[A]^c}$$

where $[A]$, $[B]$, and $[C]$ are the concentrations of $A$, $B$, and $C$ at equilibrium.

**Introduction**

This section introduces the concept of chemical equilibrium and explores the factors that affect it. The equilibrium constant, $K$, is a measure of the extent to which a reaction proceeds to completion. A large value of $K$ indicates that the reaction goes to completion, while a small value indicates that the reaction is far from equilibrium.

**Reversible Reactions**

When a reaction is reversible, the forward and reverse reactions are in constant equilibrium. The equilibrium constant can be used to calculate the concentrations of reactants and products at equilibrium.

**Consolidation**

The final topic of this unit is the relationship between chemical equilibrium and industry. The economic benefits of achieving chemical equilibrium in industrial processes are discussed, and examples of industries that rely on chemical equilibrium are provided.

---

**Key Points**

- Chemical equilibrium is a state of dynamic balance between the forward and reverse reactions of a reversible reaction.
- The equilibrium constant, $K$, is a measure of the extent to which a reaction proceeds to completion.
- The reverse reaction is balanced by the forward reaction, and the concentrations of the reactants and products remain constant.
- The equilibrium constant can be used to calculate the concentrations of reactants and products at equilibrium.
- The economic benefits of achieving chemical equilibrium in industrial processes are discussed.


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</table>

### Questions

1. Calculate the atom economy for this method of producing iron.

2. Calculate the percentage yield if only 150 tonnes of iron were obtained.

### Equilibrium Problems

- When are evaporation and condensation considered physical processes?
- Why can't water be contained in a closed container over a period of time?
- What happens to the mass of liquid and gaseous components when a closed and an open container are used?
- Why do chemical reactions stop? Does water drop condensation?
- Water molecules and ethanol in contact with water drops:
  - How does the ethanol and water molecules interact?
  - What is the difference in the molecular scale between an open container and a closed container?

### Concept of Equilibrium

The concept of equilibrium and the rate of conversion will become clearer once this section is understood. Water is present in the liquid phase and water dissolves in the liquid phase.

### Graphs

- ![Graph showing concentration of drug in blood plasma](image)

- ![Diagram showing reactions](image)

### Diagrams

- ![Diagram illustrating equilibrium and reaction rates](image)
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Concept of Equilibrium 2

According to graph (g), how long did it take to reach equilibrium?

[Diagram showing a graph with a trend line over time]

In the reaction described above, what is the meaning of the rate of reaction?

[Diagram showing a reaction mechanism]

What do you say about the rate of forward and backward reactions in dynamic equilibrium?

[Diagram showing a reaction mechanism]

What can you say about the ratio of reactants to products in a dynamic equilibrium?

[Diagram showing a reaction mechanism]

Is the graph shown a suitable representation for the chemical system described?

[Diagram showing a graph with a trend line over time]

Describe the importance of the heat exchangers attached to the converter.

[Diagram showing a diagram of a heat exchanger]

Equilibrium has been established?

[Diagram showing a graph with a trend line over time]

The diagram shows a catalytic converter for the manufacture of sulfur trioxide from oxygen and sulfur dioxide by the following reaction:

\[ \text{SO}_2 + \text{O}_2 \rightleftharpoons \text{SO}_3 \]

Calculate the percentage still unreacted on leaving the converter.

[Diagram showing a reaction mechanism]

Explain why a chemical industry such as poly(ethylene) manufacture can be described as capital-intensive rather than labour-intensive.

[Diagram showing a large factory with equipment]

In the reaction described above, what is the meaning of the rate of reaction?

[Diagram showing a reaction mechanism]

When hydrogen and bromine combine, an equilibrium reaction takes place.

\[ \text{H}_2 + \text{Br}_2 \rightleftharpoons 2\text{HBr} \]

What is the value of the enthalpy change for the dissociation of hydrogen bromide as expressed in the following equation?

\[ \text{H}_2 \rightleftharpoons 2\text{H} \]

What is happening to the rate of the backward reaction at (a)? Why?

[Diagram showing a reaction mechanism]

Ethanol can be manufactured from steam and ethene using a catalyst.

\[ \text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightleftharpoons \text{C}_2\text{H}_5\text{OH} \]

Explain why a chemical industry such as poly(ethylene) manufacture can be described as capital-intensive rather than labour-intensive.

[Diagram showing a large factory with equipment]
Equilibrium & Industry

The position of equilibrium depends on the relative concentrations of reactants and products. We say the equilibrium lies to the right if the reaction proceeds as written. If instead the reaction is reversed, the equilibrium lies to the left.

We describe the relative proportions of reactants and products by referring to the equilibrium position. One way to describe this is to compare the proportion of reactants and products at equilibrium with the initial proportions of the reactants.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Initial Proportions</th>
<th>Equilibrium Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A + B → C</td>
<td>0.1 : 0.1 : 0.1</td>
<td>0.2 : 0.0 : 0.8</td>
</tr>
</tbody>
</table>

When the concentrations of reactants and products are equal, we say that the reaction has reached equilibrium.

We can also describe the position of equilibrium by using the concept of reaction quotient (Q). The reaction quotient is a measure of the extent to which a reaction has progressed towards the product side. When Q = K_c, the reaction is at equilibrium.

\[ Q = \frac{[C]^2}{[A][B]} \]

where [A], [B], and [C] are the concentrations of A, B, and C, respectively.

**Example:**

\[ 2 \text{H}_2(g) + \text{O}_2(g) \rightleftharpoons 2 \text{H}_2\text{O}(g) \]

Given that the initial concentrations are [H}_2] = 1 M, [O] = 0.5 M, and [H}_2O] = 0 M, calculate Q and K_c and determine if the reaction is occurring to the right or left.

**Solution:**

\[ Q = \frac{[H}_2\text{O}]^2}{[H}_2]^2[\text{O}_2] = \frac{(0)^2}{(1)^2(0.5)} = 0 \]

Since Q < K_c, the reaction will proceed to the right.

**Note:** The equilibrium constant (K_c) is a measure of the extent to which a reaction proceeds to the product side. It is defined as the ratio of the concentrations of products to reactants at equilibrium.

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\[ K_c = \frac{[C]^2}{[A][B]} \]
Questions 2 to 5 refer to this esterification:

\[
\text{CH}_3\text{COO}^- + \text{H}_3\text{C}^-\text{O}^- \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}
\]

Q1. What is the catalyst commonly used for this reaction?

Q2. How much less waste is produced making 3000 tonnes of ibuprofen by the newer method compared to the old method?

Q3. About 3000 tonnes of ibuprofen tablets are used in the UK each year. Calculate the number of 2000 tonnes of ibuprofen produced by the original method of manufacture.

Q4. How much waste is produced by making 3000 tonnes of ibuprofen by the original method of manufacture?

Q5. What is the net ionic equation for this esterification?

Q6. Which of the following represents the production of only products?

\[
\text{CH}_3\text{COO}^- + \text{H}_3\text{C}^-\text{O}^- \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}
\]

A) CH₃COO⁻ + H₃C⁻O⁻  B) CH₃COOC₂H₅ + H₂O

Q7. What will be the proportion of C in the mixture at equilibrium?

Q8. How much waste is produced making 3000 tonnes of ibuprofen by the newer method invented in the 1980s had an improved atom economy?

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Study Guide - Equilibrium & Industry

Self Check

3.1

Q1.
Blue copper sulfate crystals turn white if heated but return to blue if water is added. The equation which describes this is given below.

\[
\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + 5\text{H}_2\text{O}
\]

a) Explain what the \( \rightarrow \) sign means.

b) In which direction is the reaction going if the colour change is from white to blue?

c) What must be true before this reaction can be reversible?

Q2.
Ammonia is manufactured from nitrogen and hydrogen according to the following equation.

\[
\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3
\]

a) What is the position of equilibrium in this reaction if the equilibrium mixture contains 20% ammonia?

b) Why can chemical equilibrium be described as dynamic?

c) What is actually equal in the equilibrium mixture for this reaction?

d) If the process is started from 100% ammonia what will be the percentage of ammonia once equilibrium has been established?

Q3.
Water exists in both covalent and ionic forms under normal conditions.

a) Write the equation for this equilibrium.

b) Describe the position of equilibrium in the water equilibrium reaction.

c) Which of the two reactions is favoured?

Questions 2, 3, 4 and 5 refer to the following method of making the pigment TiO\(_2\).

\[
\text{FeTiO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{TiO}_2(\text{s}) + \text{FeSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l})
\]

Q2.
Theoretically, how many tonnes of TiO\(_2\) would be produced when 76 tonnes of ilmenite, FeTiO\(_3\), are reacted.

A 32 tonnes
B 40 tonnes
C 76 tonnes
D 80 tonnes

Q3.
Calculate the % yield of TiO\(_2\) if 32 tonnes of TiO\(_2\) was produced from 76 tonnes of ilmenite.

A 42%.
B 50%.
C 66%.
D 80%.

Q4.
Assuming 100% yield, calculate the Atom Economy of this reaction.

A 32%.
B 40%.
C 76%.
D 80%.

Q5.
FeSO\(_4\) is the active ingredient in moss killer and can be sold on for this purpose. Recalculate the Atom Economy taking into account this information.

A 76%.
B 87%.
C 93%.
D 100%.

Q6.
Ethanol, C\(_2\)H\(_5\)OH, can be produced in a variety of reactions. Which has the best Atom Economy?

A C\(_2\)H\(_4\) + H\(_2\)O \rightarrow C\(_2\)H\(_5\)OH
B C\(_6\)H\(_12\)O\(_6\) \rightarrow 2 C\(_2\)H\(_5\)OH + 2 CO\(_2\)
C 4 CO + 6 H\(_2\) \rightarrow 2 C\(_2\)H\(_5\)OH + O\(_2\)
D HCOOC\(_2\)H\(_5\) \rightarrow C\(_2\)H\(_5\)OH + HCOOH

Q7.
Assuming 100% yield, the Atom Economy of this reaction is approximately

A 30%.
B 40%.
C 50%.
D 60%.

Q8.
In reality, we would consider this reaction to have an Atom Economy of

A the reaction is not reversible.
B CO\(_2\) and H\(_2\)O are readily available.
C none of the hydrogen atoms are wasted.
D the oxygen is also a desirable product.

Home Practice
Changing Conditions

The reaction rate constants change in an equilibrium mixture if the conditions are altered.

Introduction

3.2 Changing Conditions

Think about the changes made to the equilibrium mixture. For each:

1. Change in concentration of Pd

2. To the third solution add a few crystals of sodium carbonate. This increases the concentration of CN⁻ ions. The equilibrium mixture will change to a new equilibrium.

3. To the third solution add a few crystals of sodium carbonate. This decreases the concentration of CN⁻ ions. The equilibrium mixture will change to a new equilibrium.

4. Draw the structural formula for ethanoic acid.

5. What implication does this have for the atom economy of this method?

6. Explain your answer.

Think about the 3 changes made to the equilibrium mixture. For each:

1. If a new equilibrium is established...

2. What will happen if the rate of the reverse reaction is a ceat with the forward reaction?

3. What will happen if the rate of the reverse reaction is much faster than the forward reaction?

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See the information in the table above to calculate the atom economy.

TABLE 2. Atom Economy in the Green Synthesis of Ibuprofen

<table>
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<tr>
<th>Process</th>
<th>Atom Economy</th>
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<tbody>
<tr>
<td>1.</td>
<td>83%</td>
</tr>
<tr>
<td>2.</td>
<td>86%</td>
</tr>
<tr>
<td>3.</td>
<td>89%</td>
</tr>
<tr>
<td>4.</td>
<td>92%</td>
</tr>
<tr>
<td>5.</td>
<td>95%</td>
</tr>
<tr>
<td>6.</td>
<td>98%</td>
</tr>
</tbody>
</table>

What will a new equilibrium be established?

Thermal energy is used to drive a net reaction and the reaction is run in one direction only. In an equilibrium mixture, the reaction is run in both directions.

Think about the changes made to the equilibrium mixture. For each:

1. Change in concentration of Pd

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About 14 million kg of Ibuprofen is produced each year. Calculate

3. What % of the reactant atoms are not being used and find their

Economy of this method of synthesising Ibuprofen.

1. What will be exothermic in one direction and endothermic in

TABLE 1: Aromene: in the Bomon Synthesis of Aminophenol

<table>
<thead>
<tr>
<th>Product</th>
<th>Formula</th>
<th>Reactants</th>
<th>Product</th>
<th>Formula</th>
<th>Reactants</th>
</tr>
</thead>
<tbody>
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</table>

The moment of year is produced each year.

2. Why is the molar mass of alcohol and find their

When % of the reactant atoms are not being used and find their

The information in the table above is correct.

A reversed reaction will be exothermic in one direction and endothermic in

Is this reaction endothermic or exothermic?

Is the reaction endothermic or exothermic?

Is the reaction endothermic or exothermic?

Is the reaction endothermic or exothermic?

The temperature or pressure will alter the position of an equilibrium reaction.

When the temperature or pressure will alter the position of an equilibrium reaction.

However, these effects will be more noticeable for reversible and the back-end reactions.

In a pressure treatment, you learn that temperature changes

The activity chemotherapy and pressure

The catalytic mixture is transformed with the temperature of the

Proton can simplify the temperature of a reaction under the conditions of the

In a pressure treatment, you learn that temperature changes

An exercise in which the temperature changes

To test whether or not your hypothesis is correct, you will conduct an experiment. For this experiment, you will need

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The world production of ibuprofen exceeds 30 million pounds per year. 

Ibuprofen is the active ingredient in a number of brand name products for the over-the-counter treatment of pain and inflammation. In the pharmaceutical industry, 

propanone (acetone, CH₃COCH₃) is of industrial interest in a number of ways, mainly products made from it. Two of its main uses are in the manufacture of phenol, which is mainly used as a solvent and a starting material for the production of some other pitches. Another product with high demand is propan-2-ol (CH₃CHOHCH₃), which is also a desirable intermediate in the production of phenol and other products.

The continued growth of the petrochemical industry is dependent on the demand for propanone, which is rising at a lower rate than some of which can be used - mainly as a bleach in the manufacture of paper. At present, however, the process is up to 3 to 4 times more energy intensive than the cumene oxidation process, and so it is not widely used.

increased number of collisions will increase the pressure and decrease the pressure and hence the temperature of the reactant. Increasing pressure will lead to more effective collision and hence lower the number of collisions. For a given number of collisions, CH₃CHOHCH₃ will decrease the pressure and decrease the pressure and hence the temperature of the reactant. For a given number of collisions, CH₃CHOHCH₃ and the speed of reaction are increased. It will decrease a particle's speed if the pressure is increased. The pressure can only affect a reaction that goes one of the two ways that this is shown in Scheme 1, and the numbers are shown. The numbers of collisions on the next page.
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Atom Economy

The method for calculating the Atom Economy is as follows:

\[
\text{Atom Economy} = \frac{\text{mass of desired product(s)}}{\text{total mass of reactions}} \times 100
\]

This activity is about calculating the Atom Economy for a particular reaction.

For example, consider the preparation of nitrobenzene (C₆H₅NO₂) by the reaction of benzene and nitric acid (plus other possible by-products) to deal with.

We can start by assuming 100% yield and that there is a 10% loss due to reaction with water or acid.

\[
\text{Atom Economy} = \frac{123 \times (69 + 34)}{100} = 87\%
\]

We can also assume 100% yield which also shows 10% loss due to water or other by-products.

\[
\text{Atom Economy} = \frac{123}{123 + 10} = 87\%
\]

This activity considers how catalysts influence reactions and sums up all conditions.

Adding a Catalyst

Adding a catalyst to the reaction mixture can change the position of the equilibrium and can increase the reaction rate. The presence of the catalyst will speed up the reaction towards the formation of products, therefore reducing the time it takes to reach equilibrium.

However, catalysts do not change the reaction itself and are not part of the reaction. They provide an alternative pathway, with a lower activation energy, so the reaction can proceed more quickly.

The efficiency of the catalyst can be explained in terms of favouring the reaction that reduces volumes of gas, whilst low pressure favours an increase in volume.

Think about the effect of the presence of the catalyst on the reaction.
Q3. An advantage of using a catalyst in this reaction will cause the position of equilibrium in a system at equilibrium contains equal concentrations of both gases to decrease in concentration. A reversible reaction reaches equilibrium when the forward and reverse reaction rates are equal. In this case, the forward reaction is faster when a catalyst is used. A system at equilibrium contains equal concentrations of both gases to decrease in concentration. A reversible reaction reaches equilibrium when the forward and reverse reaction rates are equal.

Q4. Which reactant has the smaller mole ratio is going to run out first. Whichever reactant has the smaller mole ratio is going to run out first. The limiting reagent is the chemical reactant that limits the amount of product that can be produced (theoretically) from the reaction of the reactants. As already mentioned, the limiting reagent is the chemical reactant that limits the amount of product that can be produced (theoretically) from the reaction of the reactants.

Q5. If the number of moles of ammonia then can be calculated. (The number of moles of ammonia that can be calculated the reaction shown in the balanced equation and the number of moles in the balanced equation are equal to the number of moles of reagents or products.

Q6. What is the product yield of NH3? To determine the percentage yield of ammonia, calculate the difference between the theoretical yield and the actual yield.

Q7. Calculate the amount of NH3 that would be produced (theoretically) from the reaction of the reactant.

Q8. Both methods require this information to calculate the amount of product. Both methods require this information.

Q9. Identify the reactant giving the smaller number of moles of product. For example, how many moles of NH3 can be produced (theoretically) from the reaction of the reactant.

Q10. Equilibrium & Industry

Study Guide - CF E New Higher - Unit 3 - Topic 3

Page 40
This activity is about calculating the percentage yield of a product in a chemical reaction. The % Yield is calculated as follows: 

\[
\text{% Yield} = \frac{\text{Actual product mass}}{\text{Theoretical product mass}} \times 100 
\]

The difference between the calculated theoretical mass of product and the measured actual mass of product is the sample error. Error may be due to any of the following:

- Some product was not collected.
- Some product is not 100% pure.
- Excess of product in the sample when they are gases.
- There are some minor side reactions involving the products.

The % Yield is a measure of the efficiency with which reactants are converted into the desired product. However, this ignores other by-products which would occur and are more important to the Chemical Industry. Traditionally, this was measured in terms of the % Yield from the balanced equation. This ignored other by-products which would occur. Equilibrium is reached when there is no change in the composition of the reaction mixture.

% Yields & The Atom Economy

[Illustration of chromatography]
What is the mobile phase and the stationary phase in chromatography?

Copy and complete the flow diagram below:

1. Which environmental reason is there for siting a sulphuric acid plant next to a run of oil products?

2. What is a solvent?

3. Write balanced equations for the production of each acid:
   - Phosphoric acid
   - Glutamic acid

4. What is the main function of a hydrogenation process?

5. Write balanced equations for the production of each acid:
   - Phosphoric acid
   - Glutamic acid

6. What is the main function of a hydrogenation process?
Running a Chromatogram

1. **Prepare the Chromatogram:**
   - Use a clean TLC sheet (SiO₂ coated onto a sheet of glass).
   - Label three marks samples of known amino acids in the order of their migration.
   - Draw a pencil line below the 1st mark samples of known amino acids.
   - Draw 4th marks an unknown amino acid mixture.
   - Draw a pencil line between the 3rd and 4th marks.
   - Draw the solvent front about 3 cm from the bottom of the sheet.
   - Allow the solvent to travel up to the starting line on the TLC sheet.

2. **Identify the spots:**
   - The spots are the unknown amino acids.
   - The spots are identified by their position on the TLC sheet.

3. **Determine the order:**
   - The order is determined by the position of the spots.
   - The spots are identified by their position on the TLC sheet.

4. **Compare the spots:**
   - The spots are compared to the known amino acids.
   - The spots are identified by their position on the TLC sheet.

5. **Record the results:**
   - The results are recorded in the form of a chromatogram.
   - The results are recorded in the form of a chromatogram.

---

**Questions:**

1. **Which of the following is a fixed cost?**
   - The smelting of metal ores.
   - The equilibrium yield of sulphur trioxide.
   - The catalyst does not function at higher temperatures.

2. **What is the maximum amount of heat energy?**
   - The equilibrium yield of sulphur trioxide.
   - The catalyst does not function at higher temperatures.
   - The smelting of metal ores.

3. **Which of the following is a variable cost?**
   - The local authorities rates.
   - The equilibrium yield of sulphur trioxide.
   - The catalyst does not function at higher temperatures.

4. **What is the purpose of the TLC sheet?**
   - To see the amino acids.
   - To spray the sheet with solvent.
   - To dry the TLC sheet.

---

**Notes:**

- Describe the mechanism between the solid and the liquid phases.
- Describe the mechanism between the stationary and the mobile phase.
- Explain the principles of the solvent front.
- Explain the principles of the development.
- Explain the principles of the detection.
- Explain the principles of the visualization.
- Explain the principles of the interpretation.
- Explain the principles of the quantification.
- Explain the principles of the chromatogram.
### Study Guide - Equilibrium & Industry

**Chemical Equilibrium**

- Chemical equlibrium is achieved when the rates of the forward and reverse reactions are equal. It is a dynamic state where the concentrations of reactants and products remain constant despite the ongoing reaction.

### Costs Considerations

**Fixed Costs & Variable Costs**

- **Fixed Costs:**
  - Depreciation of plant and machinery.
  - R&D expenses.
  - Licenses for use of proprietary technology.

- **Variable Costs:**
  - Raw materials.
  - Utilities.
  - Labor.

**Break-even Analysis**

- Break-even analysis helps determine the minimum output level needed to cover all costs and reach profitability.

### Equilibrium & Industry

**Concepts**

- Le Chatelier’s Principle: If a change in conditions occurs, the system will adjust to minimize the effect of the change. This adjustment involves a change in the reaction quotient (Q) to return to the equilibrium state.

**Calculations**

- **Equilibrium Constant (K):**
  
  \[ K = \frac{[\text{products}]}{[\text{reactants}]} \]

- **Equilibrium Concentrations:**
  
  \[ K_c = \frac{[\text{products}]}{[\text{reactants}]} \]

**Equilibrium & Industry Considerations**

- **Economics:**
  - Cost advantage is achieved when production is optimized to minimize expenses.

- **Environmental Impact:**
  - Reduction in emissions and waste.

**Chromatography of Amino Acids**

- **Chromatography Technique:**
  
  - Solvent front.
  - Start.

**Retention Ratio:**

- Measure the distance (cm) from the solvent front to obtain the retention ratio.

**Product Identification:**

- By measuring the distance traveled by the solvent.

**Conclusion:**

- The chromatography of amino acids is a powerful tool for identifying and quantifying amino acids present in a sample. It is widely used in various fields, including biochemistry and medicine.
1. Consider the information given above. When you have reached decisions, check them in the table below.

<p>| | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What do you conclude from the information given above? Explain your reasoning.

3. Explain how the reactions you have considered in this question will be important to the chemical industry today.

4. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

5. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

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11. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

12. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

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15. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

16. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

17. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

18. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

19. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.

20. Explain how the reaction of sulphur trioxide with water is achieved in industry. Explain how the equilibrium position in this reaction is very different from the one obtained in the laboratory.
400 °C. However, the reaction is catalysed, so the reaction is slower near the top of the sheet, higher boiling lower down.

Stage 1: A fresh TLC sheet is spotted with sample A or some other substances as outlined earlier, or by burning melted sulphur in air. A fresh TLC sheet is prepared by drawing a light pencil starting line 1 cm from the bottom of the plate. The solvent in the tank must be deep enough to cover the whole sheet. When a TLC sheet is placed in a tank, the solvent will travel upward.

Stage 2: A TLC sheet is developed in the following solvent mixture is used. The mobile phase will remain the same.

Q1. Which of the following solvent mixtures is used in the following solvent mixture?

Q2. When a TLC sheet is placed in a tank, the solvent will travel upward.

Q3. If two substances are run on the same TLC plate, how are they separated?

Q4. The RP of a will be different from that of b.

Q5. The RP of a will be greater than that of b.

Q6. The RP of a will be equal to that of b.

Q7. The RP of a will be less than that of b.

Q8. With the following solvent mixture is used in the following solvent mixture, the mobile phase will remain the same.

Stage 3: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same. The compounds A, B & C are run on a TLC plate. A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 4: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 5: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 6: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 7: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 8: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 9: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 10: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 11: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 12: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.

Stage 13: The compounds below are run on a TLC plate.

A fresh TLC sheet is spotted with compound C. Other compounds A, B & C, but this time the amount of A will remain the same.
Copy and complete the table. Include the units.

**Sulphur Deposits**

<table>
<thead>
<tr>
<th>Source</th>
<th>Deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Large, easily extracted</td>
</tr>
<tr>
<td>UK</td>
<td>No natural deposits</td>
</tr>
<tr>
<td>Japan</td>
<td>Natural deposits</td>
</tr>
</tbody>
</table>

**Sulphur Sources**

- Raw materials for the chemical industry
- Petrochemicals, such as petrol and plastics
- Manufactured in larger quantities

**Sulphuric Acid Industry**

- Used as a raw material for the chemical industry
- Can be sold as a by-product
- Good purity which is then used to manufacture sulphuric acid

**Concepts Used**

- Rf values
- Spots obtained by chromatography can be compared using their Rf values.

**Questions**

1. Copy and complete the table. Include the units.
2. Sulphur is found as the relatively pure element in large easily extracted deposits in the USA, where it is mined for use in cement and is therefore a commercial by-product. In this case, there is no by-product to consider. On the other hand, there is the cost of importing and transporting the sulphur. In this case, there is no by-product to consider. On the other hand, there is the cost of importing and transporting the sulphur. On the other hand, there is the cost of importing and transporting the sulphur.

3. Describe two metal ions in the sample of water from the mine.

4. Suggest a colour for the spot formed by the copper(II) ions.

5. Give the formula of the copper(II) compound responsible for the colour seen.

6. Anhydrite is a mineral form of calcium sulphate, CaSO₄·H₂O, found in large quantities in some locations beside metal ore smelters. Anhydrite is a mineral form of calcium sulphate, CaSO₄·H₂O, found in large quantities in some locations beside metal ore smelters.

**Conclusion**

- Sulphuric acid plants are therefore operated in close proximity to smelters.
- Teesside to exploit this resource

**Homework**

- Copy and complete the table. Include the units.
Q1 contd.

f) Use the values you recorded in the table to calculate the Rf value for spot X.

A student wished to identify the components of over the counter pain-killers. He first obtained pure samples of the four most likely components, A, B, C, & D. He then ran a chromatogram of his first pain killer, using water as the solvent, he got two spots with Rf values of 0.54 and 0.72.

g) Use the data in the table to suggest two possible identities for the substance that caused the spot with an Rf of 0.54.

h) Describe a further chromatography experiment that should be carried out to confirm which one of the substances you have identified in g) actually caused the spot.

Total (10)

Q2. The Haber process involves the following equilibrium reaction.

\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \quad \Delta H = -92 \text{ kJ} \]

a) Why is it not economic to use a pressure of 2000 atmospheres?

b) Why is it not economic to operate the plant at room temperature?

c) Why does increasing the pressure have on the yield of ammonia in the equilibrium mixture?

d) Why does increasing the temperature have on the yield of ammonia in the equilibrium mixture?

e) What effect does using a catalyst have on the yield of ammonia in the equilibrium mixture?

f) Why is it not economic to use a pressure of 2000 atmospheres?

g) Why is it not economic to operate the plant at room temperature?

h) Why is it not economic to use a pressure of 2000 atmospheres?

Total (10)

Q3. The plant for carrying out the Haber process has a recycle loop.

a) What passes round the recycle loop?

b) Why is it economically essential to have the recycle loop?

c) How is the main product of the Haber process separated from the equilibrium mixture?

d) What would happen if the recycle loop were not in the process?

Total (10)

Q4. Home Practice

1. Study Guide - Equilibrium & Industry

CfE New Higher - Unit 3 - Topic 3

Study Guide - Equilibrium & Industry

Home Practice

3.3

1. State whether each of the following is a raw material, a by-product, or a catalyst for the Haber process.

2. Describe a further chromatography experiment that should be carried out to confirm which one of the substances you have identified in g) actually caused the spot.

3. Total (10)
The image contains a section of a chemistry textbook focused on chromatography. Here is the text from the image in a plain text format:

**Analysis: Chromatography**

**Introduction**

The activity below is one of the most common ingredients in our everyday environments.

**Analisys**

1. Introduce the properties of molecules and their interactions with solid and organic surfaces.
2. Discuss the importance of chromatography in the field of forensic science.
3. Explain how chromatography is performed and its applications.

You are already familiar with the theory behind chromatography.

**Self Check**

1. An unchanged concentration of nitrogen.
2. A greater concentration of ammonia.
3. An unchanged concentration of hydrogen.
4. A greater concentration of ammonia.

Questions 3 and 4 refer to the following.

**Questions**

Q1. An iron catalyst is used in the Haber process to convert the raw materials into ammonia.

Q2. The raw materials for the manufacture of ammonia in the UK are crude oil and nitrogen.

Q3. The iron catalyst would cause the equilibrium reaction to shift to the right.

Q4. The iron catalyst would cause the Haber process to be economic.

Q5. An iron catalyst is used in the Haber process to convert the raw materials into ammonia.

Q6. An iron catalyst is used in the Haber process to convert the raw materials into ammonia.

Q7. An iron catalyst is used in the Haber process to convert the raw materials into ammonia.

Q8. An iron catalyst is used in the Haber process to convert the raw materials into ammonia.

The image also includes diagrams and tables related to chromatography.
Step 1. Using your sample to dry until it appears all the solvent has evaporated from the spots.

Step 2. Running the Chromatograms:

4.

5.

6.

7.

8.

9.

10.

11.

12.
1. Calculate the Rf value for each spot and record in the table.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Calculated Rf value</th>
<th>Measured Rf value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5</td>
<td>0.45</td>
</tr>
<tr>
<td>B</td>
<td>0.6</td>
<td>0.45</td>
</tr>
</tbody>
</table>

2. Compare the Rf values with those of the standard compounds.

3. Conclusion

The reaction conditions are: high temperature, low pressure.

4. Conditions for a reaction to occur include: high temperature and low pressure.

5. Write the balanced chemical equation for the reaction.

\[ \text{Reactants} \rightarrow \text{Products} \]

6. Conditions for the reaction to occur: high temperature and low pressure.

7. The reaction conditions are: high temperature, low pressure.

8. Conclusion

The reaction is in equilibrium with the position of equilibrium being displaced to the right.

9. Conditions for the reaction to occur: high temperature and low pressure.

10. Write the balanced chemical equation for the reaction.

\[ \text{Reactants} \rightarrow \text{Products} \]

11. Conclusion

The reaction is in equilibrium with the position of equilibrium being displaced to the right.

12. Conditions for the reaction to occur: high temperature and low pressure.
### Challenge Chemistry

#### Introduction

The chemical processes involved in the production of ammonia are crucial to the fertilizer industry, which plays a key role in ensuring that crops can be grown on a large scale. Ammonia is manufactured from nitrogen and hydrogen by the Haber process, which is key to the whole of this industry, ammonia. It is not used itself as a fertilizer, but from the chemical fertiliser industry plays a key role in ensuring that crops can be grown on a large scale.

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ + H₂ → N₂ + 3 H₂</td>
<td>N₂ + 3 H₂ → NH₃ + O₂</td>
<td>N₂ + 3 H₂ → NH₃ + O₂</td>
</tr>
<tr>
<td>Stream combines reductant</td>
<td>Steam combines reductant</td>
<td>Steam combines reductant</td>
</tr>
<tr>
<td>CO₂ + CO → H₂O + CO</td>
<td>CO₂ + CO → H₂O + CO</td>
<td>CO₂ + CO → H₂O + CO</td>
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</tbody>
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**Elastbooks & Raw Materials**

The economic conditions of the fertilizer industry play a key role in ensuring that crops can be grown on a large scale. Ammonia is manufactured from nitrogen and hydrogen by the Haber process, which is key to the whole of this industry, ammonia. It is not used itself as a fertilizer, but from the chemical fertiliser industry plays a key role in ensuring that crops can be grown on a large scale.

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