OCR GCSE GATEWAY CHEMISTRY A · J248

CHEMISTRY



EXAM QUESTION PACK

C5.3 EQUILIBRIA

SCORE	PERCENTAGE
/79	%

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Gateway Chemistry A (9-1)

Equilibria

Please note that you may see slight differences between this paper and the original.

Candidates answer on the Question paper.

OCR supplied materials:
Additional resources may be supplied with this paper.

Other materials required:
- Pencil
- Ruler (cm/mm)

Duration: Not set

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions, unless your teacher tells you otherwise.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Where space is provided below the question, please write your answer there.
- You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number and question number(s).

INFORMATION FOR CANDIDATES

- The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and grammar and the use of specialist terminology* is assessed.
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **79**.
- The total number of marks may take into account some 'either/or' question choices.

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1(a) The reversible reaction between carbon dioxide and hydrogen makes methane and water.

$$\text{carbon dioxide} + \text{hydrogen} \rightleftharpoons \text{methane} + \text{water}$$

In a sealed container this reversible reaction forms a **dynamic equilibrium**.

What is meant by the term dynamic equilibrium?

Refer to both concentration and rate of reaction in your answer.

---

[2]

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(b) * Kayvan investigates the effect of changing the pressure and changing the temperature on this reaction.

$$\text{carbon dioxide} + \text{hydrogen} \rightleftharpoons \text{methane} + \text{water}$$

The table shows the percentage yield of methane in the equilibrium mixture under different conditions.

		Pressure in atmospheres			
		100	200	300	400
Temperature in °C	300	35%	52%	65%	80%
	600	30%	46%	58%	74%
	900	23%	37%	47%	62%
	1200	14%	25%	36%	48%

Describe what happens to the percentage yield as the pressure and temperature change and explain the effect of increasing the pressure on the rate of reaction.

[6]

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2(a) The reversible reaction between carbon dioxide and hydrogen makes methane and water.

$$\text{carbon dioxide} + \text{hydrogen} \rightleftharpoons \text{methane} + \text{water}$$

In a sealed container this reversible reaction forms a **dynamic equilibrium**.

What is meant by the term dynamic equilibrium?

Refer to both concentration and rate of reaction in your answer.

[2]

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(b) * Kayvan investigates the effect of changing the pressure and changing the temperature on this reaction.

carbon dioxide + hydrogen ⇌ methane + water

$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(l)$

The table shows the percentage yield of methane in the equilibrium mixture under different conditions.

		Pressure in atmospheres			
		100	200	300	400
Temperature in °C	300	35%	52%	65%	80%
	600	30%	46%	58%	74%
	900	23%	37%	47%	62%
	1200	14%	25%	36%	48%

Kayvan predicts that the reaction between carbon dioxide and hydrogen is endothermic and involves a reduction in the volume of gases.

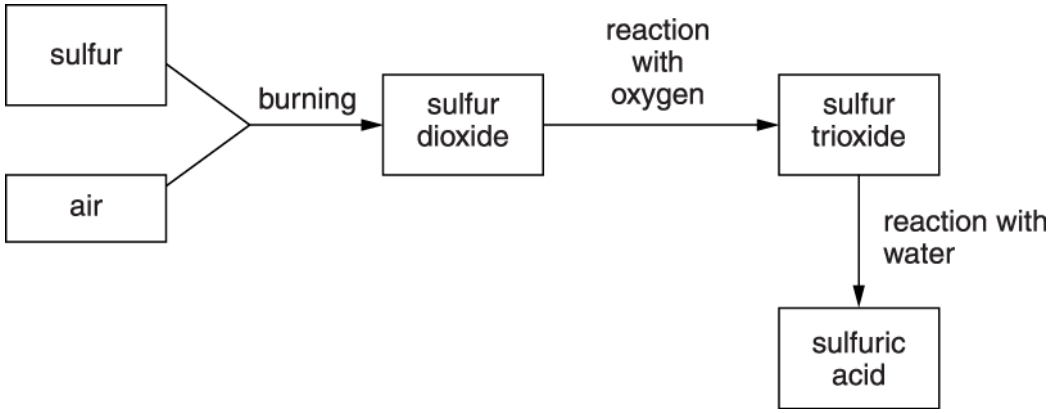
Describe and explain whether Kayvan's predictions are supported by the reaction and results in the table.

[6]

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3(a) This question is about the Contact Process used for the manufacture of sulfuric acid.

Look at the flow chart for the process.



In the process, sulfur dioxide reacts with oxygen to make sulfur trioxide.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The forward reaction is **exothermic**.

Two of the conditions used are:

- a temperature of 450 °C
- a low pressure of 3 atmospheres.

Write down **one other** condition used in the process.

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[1]

(b) Explain the choice of conditions used in the process.

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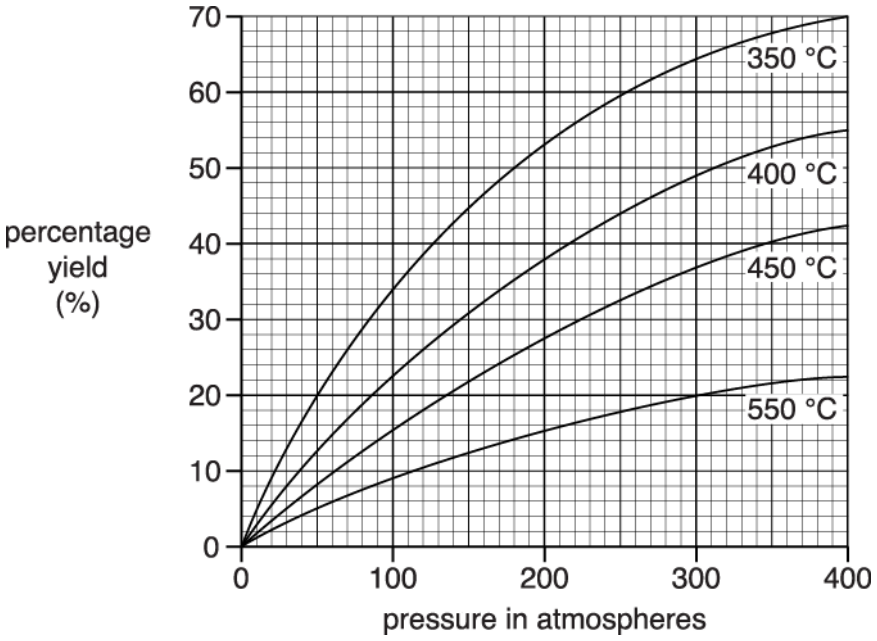
[3]

4 This question is about making ammonia by the Haber process.

Nitrogen and hydrogen react to make ammonia.

Look at the graph.

It shows the yield of ammonia under different conditions of temperature and pressure.



One cost of making ammonia is the **energy** needed.

Write about some of the **other** costs of making ammonia.

Use the graph to decide the conditions that give the **highest** yield of ammonia.

The quality of written communication will be assessed in your answer to this question.

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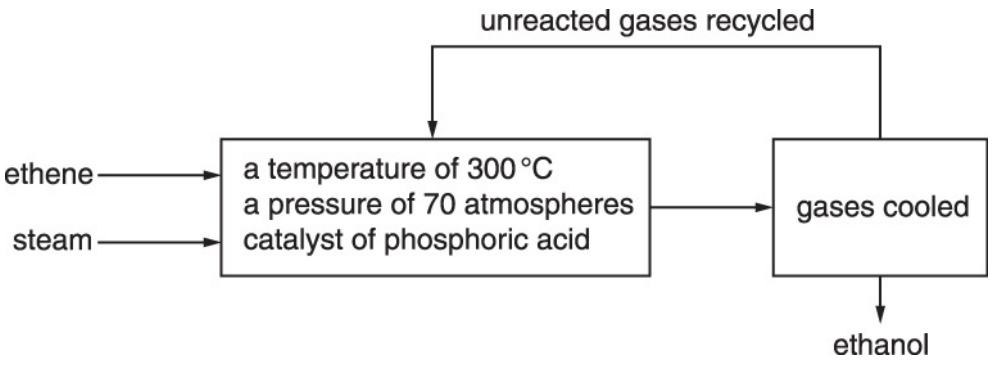
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---[6]

5(a) Ethanol (alcohol) is made by reacting ethene with steam.

$$\text{ethene} + \text{steam} \rightleftharpoons \text{ethanol}$$

Look at the flowchart.



Look at the table.

It gives some information about the percentage yield of ethanol at different temperatures and pressures.

Pressure in atmospheres	Percentage yield		
	200 °C	300 °C	400 °C
40	16	12	6
80	30	22	12
120	42	30	17
160	50	36	21

(i) What happens to the percentage yield as the **pressure** increases?

---

[1]

(ii) What happens to the percentage yield as the **temperature** increases?

---

[1]

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(b) The highest percentage yield is achieved with a temperature of 200 °C and 160 atmospheres.

The actual conditions used to make ethanol are:

- catalyst of phosphoric(V) acid
- a pressure of 70 atmospheres
- a temperature of 300 °C.

Use ideas about percentage yield and rate of reaction to suggest why each condition is used.

---

[3]

(c) This process is automated.

Explain why automation is used.

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[1]

6(a) Ethanol (alcohol) is made by reacting ethene with steam.

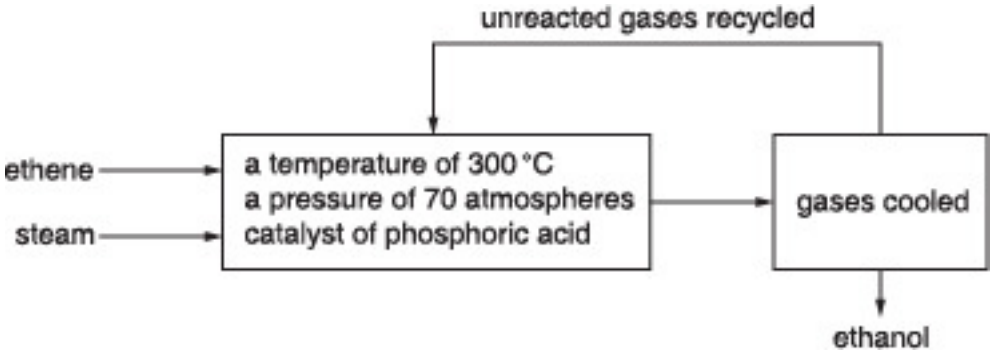
ethene + steam ? ethanol

What is meant by the symbol ? in the equation?

---

[1]

(b) Look at the flowchart.



Look at the table.

It gives some information about the percentage yield of ethanol at different temperatures and pressures.

Pressure in atmospheres	Percentage yield		
200 °C	300 °C	400 °C	
40	16	12	6
80	30	22	12
120	42	30	17
160	50	36	21

(i) What conditions give the **highest** percentage yield?

pressure _____ atmospheres

temperature _____ °C

[1]

(ii) Suggest why a pressure of 70 atmospheres is used rather than the pressure you answered in part **(i)**.

_____

_____

_____

_____ **[2]**

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7(a) In a closed system a reversible reaction will form an equilibrium mixture.

Which of the following statements are true for a reversible reaction at **equilibrium**?

Tick (✓) the **two** correct answers.

The rate of the forward reaction is faster than the rate of the backward reaction. ☐

The position of equilibrium will not change if more product is added. ☐

The concentration of the reactants does not change. ☐

The rate of the forward reaction is the same as the rate of the backward reaction. ☐

The concentration of the reactants is the same as the concentration of the products. ☐

The position of equilibrium moves to the left when product is removed from the equilibrium. ☐

[2]

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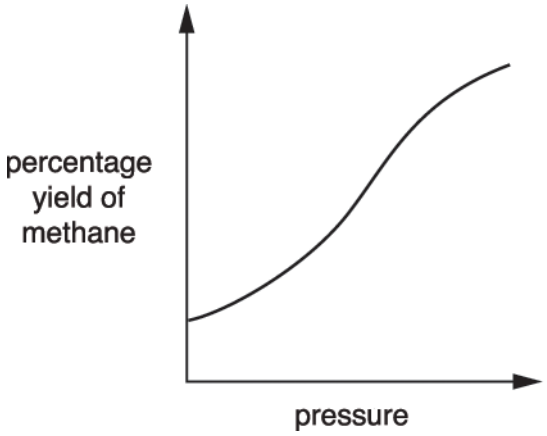
(b) Methane is a fuel that can be made by the reaction between carbon dioxide and hydrogen.

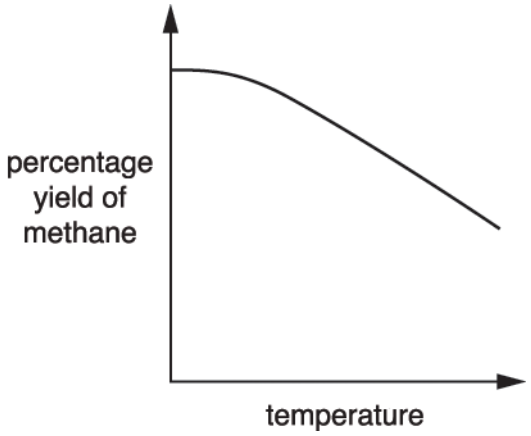
$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$$

Paul predicts that

- the reaction is exothermic
- there are more moles of gas on the right-hand side of the equation.

Look at the two graphs.





Do the graphs support Paul's predictions?

Explain your answer.

---

[2]

8 Carbon dioxide, CO_2, reacts with hydrogen, H_2, to make methanol, CH_3OH.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O\,(g)$$

Phil investigates this reversible reaction.

He mixes carbon dioxide with hydrogen.

He lets this mixture reach equilibrium.

Phil measures the percentage yield of methanol in this equilibrium mixture.

He uses different temperatures and pressures.

Look at his results.

Pressure in atmospheres	Temperature in °C			
	100	200	300	400
20	90%	81%	52%	38%
40	93%	87%	70%	58%
60	96%	92%	83%	73%
80	98%	95%	90%	83%
100	99%	97%	94%	90%

The percentage yield and position of equilibrium change with temperature, pressure and concentration of carbon dioxide.

Describe how the percentage yield of methanol changes with temperature and with pressure.

Describe how, and explain why, the position of equilibrium changes as extra carbon dioxide is added to the equilibrium mixture.



The quality of written communication will be assessed in your answer to this question.

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[6]

9 Ammonia is made from nitrogen and hydrogen in an equilibrium reaction.

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

The forward reaction is **exothermic**.

Look at **Table 1**.

It shows the percentage of ammonia in the equilibrium mixture at 450 °C and different **pressures**.

Pressure in atmospheres	Percentage (%) of ammonia at 450 °C
1	0.2
50	9.5
100	16.2
200	25.3

Table 1

Look at **Table 2**.

It shows the percentage of ammonia in the equilibrium mixture at 300 atmospheres and different **temperatures**.

Temperature in °C	Percentage (%) of ammonia at 300 atmospheres
400	50
450	35
500	25

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550	17

Table 2

Describe and explain how changing the pressure and changing the temperature affect the position of equilibrium in the reaction between nitrogen and hydrogen.

The quality of written communication will be assessed in your answer to this question.

[6]

10 Carbon dioxide, CO_2, reacts with hydrogen, H_2, to make methanol, CH_3OH.

$$CO_2 + 3H_2 \text{ ? } CH_3OH + H_2O$$

Phil investigates this reversible reaction.

He mixes carbon dioxide with hydrogen.

He lets this mixture reach equilibrium.

Phil measures the percentage yield of methanol in this equilibrium mixture.

He uses different temperatures and pressures.

Look at his results for different temperatures at a pressure of 100 atmospheres.

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Temperature in °C	Percentage yield (%)
100	99
200	97
300	94
400	90

Look at his results for different pressures at a temperature of 400 °C.

Pressure in atmospheres	Percentage yield (%)
20	38
40	58
60	73
80	83
100	90

How does the percentage yield change with temperature and with pressure?

Describe how the percentage yield is linked to the position of equilibrium.

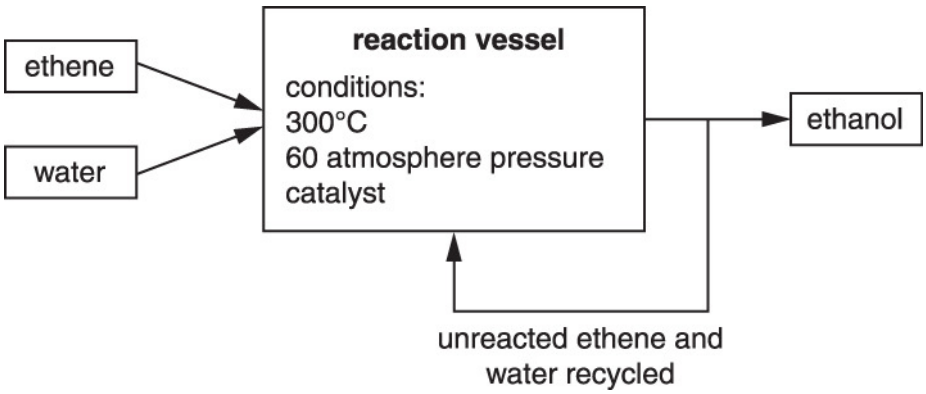


The quality of written communication will be assessed in your answer to this question.

[6]

11(a) Ethanol can be made from ethene and water.

The flowchart shows this process.



The symbol equation for the reaction is:

$$C_2H_4 + H_2O \rightleftharpoons C_2H_6O$$

The percentage of ethanol changes as the temperature and pressure change.

Look at the table.

It shows the percentage of ethanol at different temperatures and pressures.

Pressure in atmospheres	Percentage of ethanol (%)			
	At 100°C	At 200°C	At 300°C	At 400°C
20	15	10	5	2
40	20	15	10	5
60	40	30	20	10
80	60	50	40	20

Which of the following conditions gives the **highest** percentage of ethanol?

1 high pressure with high temperature
2 high pressure with low temperature
3 low pressure with high temperature
4 low pressure with low temperature

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Choose from **A**, **B**, **C** or **D**.

answer _____

[1]

(b) The conditions used for making **ethanol** are:

- 300°C
- 60 atmospheres pressure.

Suggest why these conditions are used even though the percentage of ethanol is only 20%.

_____

_____

_____ [2]

12(a) Ammonia is made from nitrogen and hydrogen in the Haber process.

Look at the equation for this reaction.

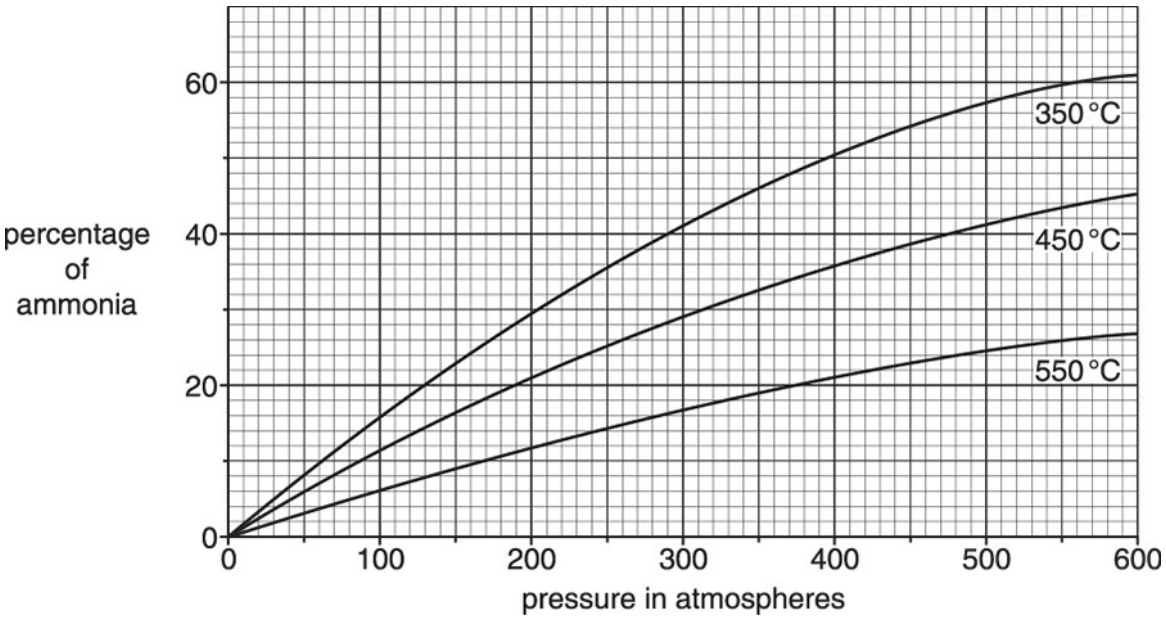
nitrogen + hydrogen ? ammonia

What does the symbol ? mean?

_____ [1]

(b) The percentage of ammonia changes as the temperature and pressure change.

Look at the graph.



Look at the graph for **350°C**.

What is the percentage of ammonia at **400 atmospheres**?

answer _____ %

[1]

13 Ammonia is made from nitrogen and hydrogen in a **reversible** reaction, which reaches an **equilibrium**.

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

Look at **Table 1**.

It shows the percentage of ammonia in the equilibrium mixture at 450 °C and different **pressures**.

Pressure in atmospheres	Percentage (%) of ammonia at 450 °C
1	0.2
50	9.5
100	16.2

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200	25.3

Table 1

Look at **Table 2**.

It shows the percentage of ammonia in the equilibrium mixture at 300 atmospheres and different **temperatures**.

Temperature in °C	Percentage (%) of ammonia at 300 atmospheres
400	50
450	35
500	25
550	17

Table 2

The reaction between nitrogen and hydrogen is a **reversible** reaction, which reaches an **equilibrium**.

What is meant by a reversible reaction which reaches an equilibrium?

How does changing the pressure and temperature affect the position of equilibrium?

The quality of written communication will be assessed in your answer to this question.

[6]

14 The Haber process is used to make ammonia, NH_3.

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

The reaction reaches a **dynamic equilibrium**.

(i) What happens to the **rate** of the forward and backward reactions at dynamic equilibrium?

[1]

(ii) What happens to the **concentrations** of the reacting substances at equilibrium?

[1]

15 Which statement describes what happens when a reaction **reaches** equilibrium?

A The forward reaction happens at a faster rate than the backwards reaction.
B The forward and backward reactions happen at the same rate.
C The forward and backward reactions stop happening.
D The backward reaction happens at a faster rate than the forward reaction.

Your answer [ ] [1]

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16(a) In the Haber process nitrogen gas, N_2, reacts with hydrogen gas.

Ammonia, NH_3, is made. The reaction is a reversible reaction.

The conditions used to make ammonia in the Haber process are:

- a pressure of 200 atmospheres
- a temperature of 450 °C.

The reaction is an exothermic reaction.

A company making ammonia increases the temperature used to 550 °C.

(i) What happens to the **rate of the reaction** when the temperature is increased?

---

[1]

(ii) The company thinks that the increase in temperature will increase the **yield** of ammonia.

Is the company correct? Explain your answer.

---

[2]

(b) The company wants to reduce the cost of making the ammonia.

They decide to reduce the pressure used to 150 atmospheres.

Write about **two** disadvantages of using a lower pressure to make ammonia.

1 ---

---

2 ---

---

[2]

17 Look at the equation for the Haber process.

$N_{27} + 3H_2 \leftrightharpoons 2NH_3$

What is meant by the symbol $\leftrightharpoons$ in the equation?

A A reaction that involves a catalyst.
B A reaction that is exothermic.
C A reaction with 100% atom economy.
D A reversible reaction.

Your answer [ ] [1]

18 The Contact process produces sulfur trioxide, SO_3, in an **exothermic** reaction.

$2SO_2 + O_2 \leftrightharpoons 2SO_3$

The temperature in the reaction vessel is usually 450 °C.

What happens as the temperature is increased to 600 °C?

A Higher rate of reaction and increased yield of sulfur trioxide.
B Higher rate of reaction and decreased yield of sulfur trioxide.
C Higher rate of reaction and no change in yield of sulfur trioxide.
D Lower rate of reaction and decreased yield of sulfur trioxide.

Your answer [ ] [1]

END OF QUESTION PAPER

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