IGCSE Chemistry

CHEMICAL EQUILIBRIUM

0620 - PAPER 4 THEORY

2026 EDITION

Q1 **0620/41/O/N/21 Q2(b)(i)-(iii)** Reversible reactions - Easy

(b) Anhydrous copper(II) sulfate is used to test for the presence of water. When this test is positive, hydrated copper(II) sulfate is formed.

(i) State the colour change seen during this test.

from ..... to ..... [2]

(ii) Complete the chemical equation to show the reaction that takes place.

$CuSO_4$ + ... $\rightleftharpoons$ $CuSO_4 \cdot 5H_2O$ [1]

(iii) State how hydrated copper(II) sulfate can be turned back into anhydrous copper(II) sulfate.

..... [1]

Q2 **0620/42/M/J/22 Q3(b)(i)** Reversible reactions - Easy

(b) One chemical property of transition elements is that they form coloured compounds.

(i) Give the colours of the following hydrated salts.

- hydrated copper(II) sulfate .....
- hydrated cobalt(II) chloride .....

[2]

Q3 0620/42/O/N/23 Q2(c)(i)-(iv) Reversible reactions - Easy

(c) Both copper and cobalt can form coloured compounds. Some of these compounds contain water of crystallisation.

(i) Define the term water of crystallisation.

.....

..... [2]

(ii) State the colour and formula of hydrated cobalt(II) chloride crystals.

colour .....

formula .....
[2]

(iii) State the colour change seen when a few drops of water are added to anhydrous copper(II) sulfate.

from ..... to ..... [2]

(iv) State how this colour change can be reversed.

..... [1]

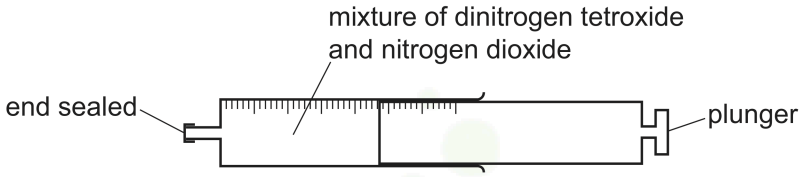
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Q4 0620/41/M/J/21 Q4 Dynamic equilibrium - Hard

4 Dinitrogen tetroxide, N_2O_4, decomposes into nitrogen dioxide, NO_2. The reaction is reversible.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

A gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide gases was sealed and heated. After reaching equilibrium the mixture was a pale brown colour.



(a) State what is meant by the term *equilibrium*.

.....

.....

..... [2]

(b) The plunger of the gas syringe is pushed in. The temperature does not change. The mixture initially turns darker brown. After a few seconds the mixture turns lighter brown because the equilibrium shifts to the left.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

(i) Explain why the mixture initially turns darker brown.

..... [1]

(ii) Explain why the position of equilibrium shifts to the left.

..... [1]

(c) The forward reaction is endothermic.

(i) State what happens to the position of equilibrium when the temperature of the mixture is increased.

..... [1]

(ii) State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is increased.

rate of the forward reaction .....

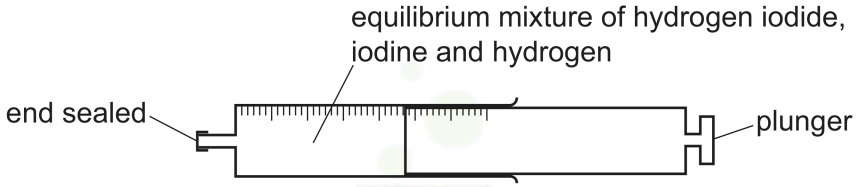
rate of the backward reaction .....
[2]

Q5 **0620/43/M/J/21 Q4** Dynamic equilibrium - Hard

4 Hydrogen iodide, HI, decomposes into iodine and hydrogen. The reaction is reversible.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

A gas syringe containing a mixture of hydrogen iodide, iodine and hydrogen gases was sealed. After reaching equilibrium the mixture was a pale purple colour.



(a) State what is meant by the term *equilibrium*.

.....

.....

..... [2]

(b) The plunger of the gas syringe is pushed in. The position of equilibrium does not change. The colour of the gaseous mixture turns darker purple.

The temperature remains constant.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

(i) Explain why the position of equilibrium does **not** change.

..... [1]

(ii) Suggest why the colour of the gaseous mixture turns darker purple even though the position of equilibrium does not change.

..... [1]

(c) The forward reaction is endothermic.

(i) State what happens to the position of equilibrium when the temperature is decreased.

.....

..... [1]

The equation for the reaction between methanoic acid and ethanol in the presence of a catalyst can be represented as shown.

$$HCOOH + CH_3CH_2OH \rightleftharpoons \mathbf{X} + H_2O \qquad \Delta H = -29.5\,kJ/mol$$

(c) The reaction is reversible and reaches an equilibrium within a closed system.

(i) State what is meant by the term closed system.

..... [1]

(ii) State **two** characteristics of an equilibrium.

1 .....

.....

2 .....

.....

[2]

(iii) Complete Table 4.1 to show the effect, if any, on the concentration of **X** at equilibrium for each change of condition.

Table 4.1

change of condition	effect on the concentration of **X** at equilibrium
temperature is decreased	
concentration of HCOOH is decreased	
concentrations of both HCOOH and CH_3CH_2OH are decreased	
the catalyst is removed	

[4]

Q7 0620/43/M/J/24 Q4(a)-(c) Dynamic equilibrium - Hard

4 Dinitrogen tetroxide, N_2O_4, decomposes into nitrogen dioxide, NO_2.The reaction is reversible.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

Fig. 4.1 shows a gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide. The gas syringe is sealed. The mixture reaches equilibrium and the colour of the mixture of gases is a pale brown.

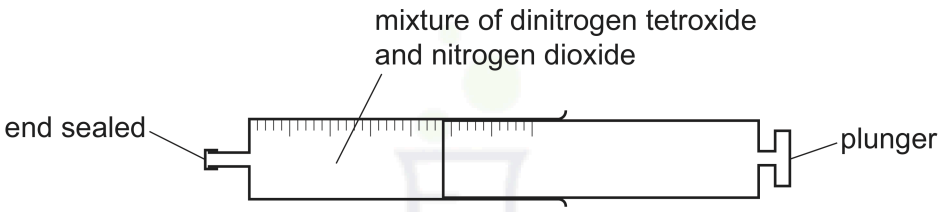


Fig. 4.1

(a) Describe a reversible reaction at equilibrium in terms of:

- the rate of the forward reaction and the rate of the reverse reaction

.....

- the concentration of reactants and products.

.....

[2]

(b) The pressure of the mixture is increased. All other conditions stay the same.

The mixture immediately turns darker brown before the position of equilibrium changes.

Explain in terms of particles why the mixture immediately turns darker brown.

..... [1]

(c) The temperature of the mixture is increased. All other conditions stay the same.

The mixture turns darker brown.

State what can be deduced about the forward reaction from this information.

.....[1]

Q8 0620/41/M/J/25 Q5(a)-(b) Dynamic equilibrium - Hard

5 Methanol, CH_3OH, is manufactured by the reaction between hydrogen and carbon monoxide.

An equilibrium mixture is produced.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

(a) State what happens to the concentration of CH_3OH when the reaction is at equilibrium.

Explain your answer in terms of rate of forward and reverse reactions.

.....

.....

..... [2]

(b) The reaction is carried out at a pressure of 75 atmospheres and a temperature of 250 °C.

(i) State **two** disadvantages of using a pressure **below** 75 atmospheres.

1 .....

2 .....

[2]

(ii) Complete Table 5.1 using **only** the words **increases**, **decreases** or **no change**.

Table 5.1

	effect on the concentration of $CH_3OH(g)$ at equilibrium	effect on the rate of the reverse reaction
catalyst is added		

[2]

(iii) If a temperature of more than 250 °C is used, the yield of methanol decreases.

State what can be deduced about the forward reaction.

..... [1]

(iv) Suggest which of the elements from the list is a suitable catalyst for the reaction. Give a reason for your answer.

barium **carbon** **copper** **potassium** **sulfur**

catalyst .....

reason .....

[2]

Q9 0620/43/O/N/25 Q4(a) Dynamic equilibrium - Hard

4 This question is about chlorine and compounds of chlorine.

(a) Gaseous chlorine reacts with gaseous phosphorus(III) chloride to form gaseous phosphorus(V) chloride. The reaction is a reversible reaction.

When the three gases are in a closed container the system reaches equilibrium.

$$Cl_2(g) + PCl_3(g) \rightleftharpoons PCl_5(g)$$

(i) Describe a reversible reaction at equilibrium in terms of:

- the rate of the forward reaction and the rate of the reverse reaction

.....

- the concentrations of reactants and products.

.....

[2]

(ii) Complete Table 4.1 using only the words **increases**, **decreases** or **no change**.

Table 4.1

change to condition	effect on the rate of the forward reaction	effect on the equilibrium concentration of PCl_5
the pressure is decreased		
a catalyst is added	increases	

[3]

(iii) When the temperature of the equilibrium mixture is increased, the equilibrium concentration of PCl_5 decreases.

State what conclusion about the forward reaction can be made from this information.

..... [1]

Q10 **0620/42/F/M/25 Q4(a),(e)** Factors affecting equilibrium - Hard

4 Carbonyl chloride, $COCl_2$, is manufactured by reacting carbon monoxide with chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -105\ kJ/mol$$

The process takes place in a closed system, and an equilibrium is reached.
The conditions for this process are 200 °C and 200 kPa.

(a) Explain what is meant by the term closed system.

.....**[1]**

(e) Complete Table 4.1 to show the effect, if any, on the concentration of $COCl_2(g)$ at equilibrium when the following changes to the conditions are applied.

Use only the words **increases**, **decreases** or **no change**.

Table 4.1

change to conditions	effect on the concentration of $COCl_2(g)$ at equilibrium
the temperature is increased	
some CO is added	
the pressure is increased	
a catalyst is added	

[4]

Q11 **0620/41/M/J/22 Q5(a)-(c)** Factors affecting equilibrium - Hard

5 Ethanoic acid is manufactured by the reaction of methanol with carbon monoxide.

An equilibrium mixture is produced.

$$CH_3OH(g) + CO(g) \rightleftharpoons CH_3COOH(g)$$

(a) State **two** characteristics of an equilibrium.

1 .....

2 .....

[2]

(b) The purpose of the industrial process is to produce a high yield of ethanoic acid at a high rate of reaction.

The manufacture is carried out at a temperature of 300 °C.

The forward reaction is exothermic.

Use this information to state why the manufacture is **not** carried out at temperatures:

- **below** 300 °C

.....

- **above** 300 °C.

.....

[2]

(c) Complete the table using only the words *increases*, *decreases* or *no change*.

	effect on the rate of the forward reaction	effect on the equilibrium yield of $CH_3COOH(g)$
adding a catalyst		no change
decreasing the pressure		

[2]

Q12 **0620/43/M/J/22 Q4(a)-(b)** Factors affecting equilibrium - Hard

4 Ethanol is made industrially by the reaction of ethene with steam. The reaction occurs at a temperature of 300 °C and a pressure of 60 atmospheres.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

A catalyst is used in this reaction.

The forward reaction is exothermic.

(a) State what is meant by the term *catalyst*.

.....

..... [2]

(b) Complete the table using only the words *increases*, *decreases* or *no change*.

	effect on the rate of the forward reaction	effect on the equilibrium yield of $C_2H_5OH(g)$
increasing the temperature		
decreasing the pressure		

[4]

Q13 **0620/42/M/J/24 Q4(e)** Factors affecting equilibrium - Hard

4 A carboxylic acid reacts with an alcohol to produce an ester and water.

Under certain conditions, this reaction can be reversed so an ester reacts with water to produce a carboxylic acid **X** and an alcohol **Y**.

The reaction reaches an equilibrium.

$$CH_3CH_2COOCH_3 + H_2O \rightleftharpoons \mathbf{X} + \mathbf{Y}$$

The forward reaction is endothermic.

Q13 (continued) **0620/42/M/J/24 Q4(e)** Factors affecting equilibrium - Hard

(e) Complete Table 4.1 to show the effect, if any, for each change of condition.

Table 4.1

change of condition	effect on the concentration of carboxylic acid **X** at equilibrium
temperature is decreased	
concentration of $CH_3CH_2COOCH_3$ is decreased	
more alcohol **Y** is added	
a catalyst is added	

[4]

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Q14 **0620/41/O/N/23 Q5(a)-(b)** Factors affecting equilibrium - Hard

5 Methane reacts with steam to produce hydrogen gas.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +200\,kJ/mol$$

The reaction takes place at 1000 °C and 100 kPa pressure.

(a) The reaction is reversible and reaches an equilibrium in a closed system.

State **two** features of an equilibrium.

1 .....

2 .....

[2]

(b) State and explain, in terms of equilibrium, what happens to the concentration of hydrogen when:

(i) the pressure is increased

.....

..... [2]

(ii) the temperature is increased

.....

..... [2]

(iii) a catalyst is used.

.....

[2]

Q15 **0620/42/O/N/23 Q5(b)(i)-(ii)** Factors affecting equilibrium - Hard

(b) Tetrachloromethane gas, $CCl_4(g)$, reacts with steam as shown.

$$CCl_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4HCl(g)$$

The reaction is reversible. The forward reaction is exothermic.

(i) State what happens, if anything, to the rate of the forward reaction if the concentration of CCl_4 is increased.
Explain your answer in terms of collision theory.

.....

.....

.....

..... [3]

(ii) State what happens to the position of equilibrium, if anything, when the pressure is increased.
Explain your answer.

.....

..... [2]

Q16 **0620/42/O/N/24 Q3(d)** Factors affecting equilibrium - Hard

(d) Chloride **P** is converted to chloride **Q** by reaction with chlorine in a closed system.
The reversible reaction reaches an equilibrium.

$$\underset{\textbf{P}}{S_2Cl_2(g)} + Cl_2(g) \rightleftharpoons \underset{\textbf{Q}}{2SCl_2(g)}$$

The forward reaction is exothermic.

Suggest **two** changes to the conditions which will result in a decrease in the concentration of chloride **Q** at equilibrium.

1 .....

2 .....

[2]

Q17 **0620/43/O/N/24 Q5(d)** Factors affecting equilibrium - Hard

(d) Nitrogen monoxide gas, NO, and oxygen gas, O_2, react to produce nitrogen dioxide gas, NO_2, at room temperature.

The reaction can reach equilibrium. The equation is shown.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113\,kJ/mol$$

NO(g) and O_2(g) are passed into a beaker as shown in Fig. 5.3.

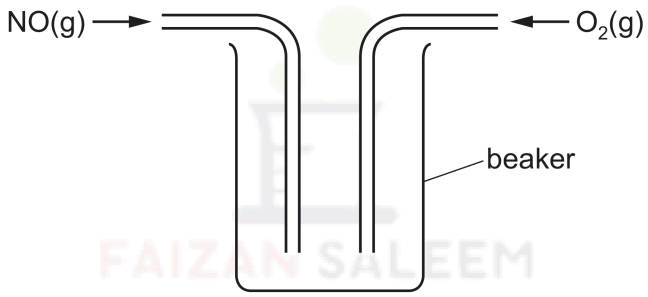


Fig. 5.3

(i) Explain why the method shown in Fig. 5.3 will **not** allow the reaction to reach equilibrium.

..... [1]

(ii) The apparatus is changed and equilibrium is reached.

The temperature of the equilibrium system is then increased and the position of equilibrium shifts to the left.

Explain why the position of equilibrium shifts to the left.

..... [1]

(iii) The pressure of the equilibrium system is then increased.

State the direction, if any, in which the position of equilibrium shifts.
Explain your answer.

direction .....

explanation .....
[2]

Q18 **0620/41/O/N/25 Q4(c)-(d)** Factors affecting equilibrium - Hard

(c) The equation for the reaction is shown.

$$SF_4(g) + 2H_2O(g) \rightleftharpoons SO_2(g) + 4HF(g) \qquad \Delta H = -54\,kJ/mol$$

State the effect, if any, on the position of equilibrium when the following changes are made.

Give a reason for each of your answers.

- The temperature is increased.

.....

.....

- The pressure is increased.

.....

.....

- A catalyst is added.

.....

.....

[5]

(d) Explain, in terms of collision theory, why reducing the temperature decreases the rate of the reverse reaction.

.....

.....

.....

.....

..... [3]

Q19 **0620/41/M/J/22 Q4(a)(ii)** Industrial equilibrium processes - Easy

4 This question is about compounds of sulfur.

(a) Sulfuric acid, H_2SO_4, is manufactured using the Contact process. This manufacture involves four stages.

stage 1 Molten sulfur burns in air to produce sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

(ii) State the essential conditions that are necessary for **stage 2**. Write an equation for the chemical reaction that occurs.

.....

.....

.....

[4]

Q20 **0620/43/M/J/22 Q3(b)** Industrial equilibrium processes - Easy

(b) Nitrogen reacts with hydrogen to form ammonia, NH_3, in the Haber process.

State the essential conditions in the Haber process. Write an equation for the chemical reaction.

.....

.....

.....

.....

[4]

Q21 **0620/43/M/J/23 Q6(a)** Industrial equilibrium processes - Easy

6 This question is about nitrogen and compounds of nitrogen.

(a) Ammonia is manufactured by the reaction between nitrogen and hydrogen in the Haber process.
The equation is shown.

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

(i) State the source of nitrogen for the Haber process.

..... [1]

(ii) State the source of hydrogen for the Haber process.

..... [1]

(iii) State the typical conditions used in the Haber process.

temperature ..... °C

pressure ..... atm

[2]

(iv) Name the catalyst used in the Haber process.

..... [1]

(v) State what is meant by the term catalyst.

.....

..... [2]

Q22 **0620/41/M/J/25 Q4(b)** Industrial equilibrium processes - Easy

(b) Ammonia, NH_3, is manufactured by reacting nitrogen with hydrogen, H_2, in the Haber process.

(i) State **three** typical conditions for the reaction between nitrogen and hydrogen in the Haber process.

1 .....

2 .....

3 .....

[3]

(ii) Write the symbol equation for the chemical reaction in the Haber process.

..... [1]

Q23 **0620/43/M/J/25 Q4(a),(b)** Industrial equilibrium processes - Easy

4 This question is about compounds of sulfur.

(a) Sulfuric acid is manufactured in a four-stage process.

stage 1 Sulfur dioxide is produced from ores containing sulfur.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide reacts with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4 Oleum reacts with water to form concentrated sulfuric acid.

(b) **(i)** State **three** typical conditions for the reaction between sulfur dioxide and oxygen in **stage 2**.

1 .....

2 .....

3 .....

[3]

(ii) Write a symbol equation for the reaction that occurs in **stage 2**.

..... [1]

(iii) Write the symbol equation for the reaction in **stage 3**.

..... [1]

Q24 **0620/42/O/N/21** Q5(e) Industrial equilibrium processes - Easy

(e) Iron is a typical transition element. It is the catalyst used in the Haber process.

(i) Write the equation for the reaction that occurs in the Haber process.

..... [2]

(ii) State the temperature and pressure used in the Haber process. Include units.

temperature .....

pressure .....

[2]

Q25 **0620/43/O/N/22 Q5(a)(i)** Industrial equilibrium processes - Easy

5 This question is about sulfuric acid, H_2SO_4, and salts that can be made from sulfuric acid.

(a) Sulfuric acid is manufactured by the Contact process.

stage 1 Molten sulfur burns in air to produce sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide, SO_3.

stage 3 Sulfur trioxide reacts with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4 Oleum is converted into sulfuric acid.

(i) The equation for the reaction in **stage 2** is shown.

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

State the temperature and pressure used in **stage 2**.

Name the catalyst used in **stage 2**.

temperature ..... °C

pressure ..... atm

catalyst .....

[3]

Q26 **0620/43/O/N/23 Q3(a)** Industrial equilibrium processes - Easy

3 This question is about nitrogen and some of its compounds.

(a) Nitrogen is converted into ammonia, NH_3, in the Haber process.

(i) Nitrogen is obtained from air.

State the percentage of nitrogen in clean, dry air.

..... [1]

(ii) State the source of hydrogen for the Haber process.

.....[1]

(iv) Write a chemical equation for the reaction occurring in the Haber process and give the typical reaction conditions. Include units where appropriate.

chemical equation .....

reaction conditions:

temperature .....

pressure .....

catalyst .....

[5]

Q27 **0620/42/F/M/21 Q3(a)(i)-(v)** Industrial equilibrium processes - Hard

3 This question is about ammonia.

(a) Nitrogen reacts with hydrogen to form ammonia in an industrial process.

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

(i) Name this industrial process.

..... [1]

(ii) State the meaning of the symbol $\rightleftharpoons$.

..... [1]

(iii) State the conditions used in this industrial process. Include units.

temperature .....

pressure .....

[2]

(iv) Name the catalyst used in this industrial process.

..... [1]

(v) If the pressure is increased, the yield of ammonia increases.

Explain why, in terms of equilibrium.

.....

.....

[2]

Q28 **0620/42/F/M/23 Q3(a),(b)(iii)-(iv)** Industrial equilibrium processes - Hard

3 The Haber process is used to manufacture ammonia.

(a) State the main source of each gas used in the Haber process.

nitrogen .....

hydrogen .....

[2]

Q28 (continued) **0620/42/F/M/23 Q3(a),(b)(iii)-(iv)** Industrial equilibrium processes - Hard

(b) The equation for the Haber process is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ/mol$$

The reaction is reversible. The forward reaction is exothermic.

(iii) State the typical conditions and name the catalyst used in the Haber process.

temperature ..... °C

pressure ..... kPa

catalyst .....

[3]

(iv) Complete Table 3.1 to show the effect, if any, when the typical conditions in the Haber process are changed. Use only the words **increases**, **decreases** or **no change**.

Table 3.1

change to typical conditions	effect on the rate of the forward reaction	effect on the concentration of $NH_3(g)$ at equilibrium
temperature increases	increases	
pressure decreases		
no catalyst	decreases	

[4]

Q29 **0620/41/M/J/23 Q6(b)** Industrial equilibrium processes - Hard

6 This question is about sulfur and compounds of sulfur.

Sulfur is converted into sulfuric acid, H_2SO_4, by the Contact process.

The process involves four stages.

stage 1 Molten sulfur is converted into sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

Q29 (continued) **0620/41/M/J/23 Q6(b)** Industrial equilibrium processes - Hard

(b) The equation for **stage 2** is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The forward reaction is exothermic.
The reaction is carried out at a temperature of 450 °C and a pressure of 2 atm.

Using explanations that do **not** involve cost:

(i) explain why a temperature greater than 450 °C is **not** used

.....

..... [1]

(ii) explain why a pressure lower than 2 atm is **not** used.

.....

[1]

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Q30 | 0620/42/M/J/23 Q3(a)-(b)(v) | Industrial equilibrium processes - Hard

3 Over 200 million tonnes of sulfuric acid are manufactured every year.

(a) State the name of the process used to manufacture sulfuric acid.

..... [1]

(b) Part of the manufacture of sulfuric acid involves converting sulfur dioxide to sulfur trioxide.

(i) Describe **two** methods by which sulfur dioxide is obtained.

1 .....

2 .....
[2]

The conversion of sulfur dioxide to sulfur trioxide is a reversible reaction which can reach equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(ii) State **two** features of an equilibrium.

1 .....

2 .....
[2]

(iii) State the typical conditions and name the catalyst used in the conversion of sulfur dioxide to sulfur trioxide.

temperature ..... °C

pressure ..... kPa

catalyst .....

(iv) Complete Table 3.1 to show the effect, if any, when the following changes are applied to the conversion of sulfur dioxide to sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The forward reaction is exothermic.

Only use the words **increases**, **decreases** or **no change**.

Table 3.1

change	effect on the rate of the forward reaction	effect on the concentration of $SO_3(g)$ at equilibrium
temperature decreases	decreases	
pressure increases		
no catalyst	decreases	

[4]

(v) Explain in terms of collision theory why reducing the temperature decreases the rate of the forward reaction.

.....

.....

.....

.....

[3]

Q31 **0620/41/O/N/21 Q4(b)** Industrial equilibrium processes - Hard

(b) Sulfur dioxide is then converted to sulfur trioxide.

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

The reaction is exothermic. It is also an equilibrium.

(i) State **two** features of an equilibrium.

1 .....

2 .....
[2]

(ii) State the temperature and pressure used in this reaction.
Include units.

- temperature .....
- pressure .....
[2]

(iii) Name the catalyst used.

..... [1]

(iv) Explain why a catalyst is used.

..... [1]

(v) Describe and explain, in terms of equilibrium, what happens when the temperature is increased.

.....

..... [2]

Q32 0620/42/O/N/22 Q3(c)-(d) Industrial equilibrium processes - Hard

(c) Name the industrial process used to manufacture sulfuric acid.

..... [1]

(d) The reaction that produces sulfur trioxide is an equilibrium. The forward reaction is exothermic.

(i) State the temperature and pressure used to make sulfur trioxide.

temperature = ... °C

pressure = ... atm
[2]

(ii) Name the catalyst used.

..... [1]

(iii) Describe **two** features of an equilibrium.

1 .....

2 .....
[2]

(iv) State the effect, if any, on the position of equilibrium when the following changes are made.

Explain your answers.

temperature is increased .....

.....

pressure is increased .....

.....
[4]

(v) Explain, in terms of particles, what happens to the rate of reaction when the temperature is increased.

.....

.....

.....

.....
[3]

Q1 **0620/41/O/N/21 Q2(b)(i)-(iii)** Reversible reactions - Easy

2(b)(i)	**M1** white (1) **M2** to (light) blue (1)	**2**
2(b)(ii)	$5H_2O$	**1**
2(b)(iii)	heating	**1**

Q2 **0620/42/M/J/22 Q3(b)(i)** Reversible reactions - Easy

3(b)(i)	blue pink	**2**

Q3 **0620/42/O/N/23 Q2(c)(i)-(iv)** Reversible reactions - Easy

2(c)(i)	**M1** water molecules (1) **M2** (the water present) in hydrated crystals (1)	**2**
2(c)(ii)	**M1** pink (1) **M2** $CoCl_2 \cdot 6H_2O$ (1)	**2**
2(c)(iii)	**M1** white (1) **M2** blue (1)	**2**
2(c)(iv)	heating (the hydrated copper(II) sulfate)	**1**

Question	Answer	Marks

Q4 **0620/41/M/J/21 Q4** Dynamic equilibrium - Hard

4(a)	the **rate** of forward reaction equals the rate of the reverse reaction (1) **concentrations** of reactants and products are constant (1)	**2**
4(b)(i)	(increased pressure) nitrogen dioxide **particles** or **molecules** (forced) clos**er** together **OR** same number of nitrogen dioxide **particles** or **molecules** in a small**er** volume	**1**

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4(b)(ii)	few**er** number of gas moles or molecules on left hand side or reactant side (of the equation) **ORA**	**1**
4(c)(i)	shifts to the right	**1**

Q4 (continued) **0620/41/M/J/21 Q4** Dynamic equilibrium - Hard

4(c)(ii)	increase / faster (1) increase / faster (1)	2

Question	Answer	Marks

Q5 **0620/43/M/J/21 Q4** Dynamic equilibrium - Hard

4(a)	the **rate** of forward reaction equals (the rate of the) reverse reaction (1) concentrations of reactants and products are constant (1)	2
4(b)(i)	same number of gas moles on both sides of the equilibrium / same number of gas molecules on both sides of the equilibrium	1
4(b)(ii)	iodine **particles** or **molecules** (forced) closer together / same number of iodine **particles** or **molecules** in a smaller volume	1
4(c)(i)	shifted to the left	1

Q6 **0620/42/F/M/24 Q4(c)** Dynamic equilibrium - Hard

4(c)(i)	nothing can enter or leave	1
4(c)(ii)	**M1** the rate of forward reaction equals (the rate of the) reverse reaction **M2** concentrations of reactants and products are constant	2

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4(c)(iii)	**M1** increases **M2** decreases **M3** decreases **M4** no effect	4

Question	Answer	Marks

Q7 **0620/43/M/J/24 Q4(a)-(c)** Dynamic equilibrium - Hard

4(a)	M1 (rates are) equal M2 (concentrations are) no longer changing	2
4(b)	more molecules of nitrogen dioxide per unit volume OR same number of nitrogen dioxide molecules in a smaller volume	1

Q7 (continued) **0620/43/M/J/24 Q4(a)-(c)** Dynamic equilibrium - Hard

4(c)	(the forward reaction is) endothermic	1

Q8 **0620/41/M/J/25 Q5(a)-(b)** Dynamic equilibrium - Hard

5(a)	**M1** concentration is no longer changing **M2** rates of forward reaction and of the reverse reaction are equal	2
5(b)(i)	**M1** rate decreases **M2** yield of methanol decreases	2
5(b)(ii)	no change(1) | increases (1)	2
5(b)(iii)	exothermic	1
5(b)(iv)	**M1** copper **M2** transition element	2

Q9 **0620/43/O/N/25 Q4(a)** Dynamic equilibrium - Hard

4(a)(i)	• rates are equal • concentrations are no longer changing	2
4(a)(ii)	**M1** decreases | **M2** decreases **M3** no change	3
4(a)(iii)	forward reaction is exothermic	1

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MARKING SCHEME

Q10 **0620/42/F/M/25 Q4(a),(e)** Factors affecting equilibrium - Hard

4(a)	no reactants or products can enter or leave	1
4(e)	decreases increases increases no change	4

Q11 **0620/41/M/J/22 Q5(a)-(c)** Factors affecting equilibrium - Hard

5(a)	the **rate** of forward reaction equals the rate of the reverse reaction (1) **concentrations** of reactants and products are constant (1)	2
5(b)	reaction too slow (1) yield of ethanoic acid too low (1)	2
5(c)	increases (1) | decreases (1) | decreases (1)	3

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Q12 **0620/43/M/J/22 Q4(a)-(b)** Factors affecting equilibrium - Hard

4(a)	(a substance which) increases the rate of a reaction remains unchanged or unaffected or without changing mass	2
4(b)	increases (1) | decreases (1) decreases (1) | decreases (1)	4

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Q13 **0620/42/M/J/24 Q4(e)** Factors affecting equilibrium - Hard

4(e)	**M1** decreases **M2** decreases **M3** decreases **M4** no effect	4

Q14 **0620/41/O/N/23 Q5(a)-(b)** Factors affecting equilibrium - Hard

5(a)	**M1** the rate of forward reaction equals (the rate of the) reverse reaction (1) **M2** the concentrations of reactants and products are no longer changing (1)	**2**
5(b)(i)	**M1** concentration decreases (1) **M2** position of equilibrium shifts to left **AND** fewer moles of gas on left hand side (1)	**2**
5(b)(ii)	**M1** concentration increases (1) **M2** position of equilibrium shifts to the right **AND** forward reaction is endothermic (1)	**2**
5(b)(iii)	**M1** no change (1) **M2** catalysts do not affect position of equilibrium (1)	**2**

Q15 **0620/42/O/N/23 Q5(b)(i)-(ii)** Factors affecting equilibrium - Hard

5(b)(i)	**M1** rate of reaction increases (1) **M2** more (CCl_4) particles per unit volume (1) **M3** frequency of collisions between (CCl_4 and H_2O) particles increases (1)	**3**
5(b)(ii)	**M1** (position of) equilibrium moves to left hand side (1) **M2** more (gaseous) moles / molecules on right hand side (1)	**2**

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Q16 **0620/42/O/N/24 Q3(d)** Factors affecting equilibrium - Hard

3(d)	**M1** decrease concentration of S_2Cl_2 / P and / or Cl_2 **M2** increase temperature	**2**

Q17 **0620/43/O/N/24 Q5(d)** Factors affecting equilibrium - Hard

5(d)(i)	not a closed system	**1**
5(d)(ii)	forward reaction is exothermic	**1**

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5(d)(iii)	**M1** (to the) right **M2** there are fewer gas molecules on the right	**2**

Question	Answer	Marks

Q18 **0620/41/O/N/25 Q4(c)-(d)** Factors affecting equilibrium - Hard

4(c)	increased temperature: **M1** (position of) equilibrium moves to left hand side **M2** reaction is exothermic increased pressure: **M3** (position of) equilibrium moves to left hand side **M4** less (gaseous) moles on left hand side **M5** no change / catalyst does not affect position of equilibrium	**5**

4(d)	**M1** kinetic energy of particles decreases **M2** frequency of collisions between particles decreases **M3** lower percentage/proportion/fraction of collisions / particles have energy greater than / equal to activation energy	**3**

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Q19 **0620/41/M/J/22 Q4(a)(ii)** Industrial equilibrium processes - Easy

4(a)(ii)	(temperature) 450 °C (1) (pressure) 1–2 atmosphere(s) (1) vanadium(V) oxide catalyst (1) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (1)	**4**

Q20 **0620/43/M/J/22 Q3(b)** Industrial equilibrium processes - Easy

3(b)	450 °C (1) 200 atmospheres (1) iron (catalyst) (1) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1)	**4**

Q21 **0620/43/M/J/23 Q6(a)** Industrial equilibrium processes - Easy

6(a)(i)	air	**1**
6(a)(ii)	methane	**1**
6(a)(iii)	**M1** 450 (°C) **M2** 200 (atm)	**2**
6(a)(iv)	iron	**1**

Q21 (continued) **0620/43/M/J/23 Q6(a)** Industrial equilibrium processes - Easy

6(a)(v)	**M1** (a substance which) increases the rate of a reaction **M2** remains unchanged at the end of the reaction	**2**

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Q22 **0620/41/M/J/25 Q4(b)** Industrial equilibrium processes - Easy

4(b)(i)	**Conditions can be in any order** **M1** (temperature) 450 **and** °C **M2**(pressure) 200 **and** atmospheres / 20 000 **and** kPa **M3** iron **and** catalyst	**3**
4(b)(ii)	$N_2 + 3H_2 \rightleftharpoons 2NH_3$	**1**

Q23 **0620/43/M/J/25 Q4(a),(b)** Industrial equilibrium processes - Easy

4(b)(i)	**M1** (temperature) 450 **and** °C **M2** (pressure) 2 **and** atm **OR** 200 **and** kPa **M3** vanadium(V) oxide **catalyst**	**3**
4(b)(ii)	$2SO_2 + O_2 \rightleftharpoons 2SO_3$	**1**
4(b)(iii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$	**1**

Q24 **0620/42/O/N/21 Q4(e)** Industrial equilibrium processes - Easy

5(e)(i)	$N_2 + 3H_2 \rightarrow 2NH_3$ species (1) correct equation (1)	**2**
5(e)(ii)	450 °C (1) 200 atm (1)	**2**

Q25 **0620/43/O/N/22 Q5(a)(i)** Industrial equilibrium processes - Easy

5(a)(i)	**M1** 450 (1) **M2** 1-2 (1) **M3** vanadium (V) oxide (1)	**3**

Q26 **0620/43/O/N/23 Q3(a)** Industrial equilibrium processes - Easy

3(a)(i)	78	**1**
3(a)(ii)	natural gas	**1**
3(a)(iv)	**M1** $N_2 + 3H_2 \rightarrow 2NH_3$ (1) **M2** $\rightleftharpoons$ (1) **M3** 450 °C (1) **M4** 200 atmospheres / 20 000 kPa (1) **M5** iron (1)	**5**

Q27 **0620/42/F/M/21 Q3(a)(i)-(v)** Industrial equilibrium processes - Hard

3(a)(i)	Haber	**1**
3(a)(ii)	reversible / equilibrium	**1**
3(a)(iii)	450 °C (1) 200 atm (1)	**2**
3(a)(iv)	iron / Fe	**1**
3(a)(v)	equilibrium **shifts / moves** in forwards direction (1) fewer molecules / moles (of gas) on RHS (1)	**2**

Q28 **0620/42/F/M/23 Q3(a),(b)(iii)-(iv)** Industrial equilibrium processes - Hard

3(a)	nitrogen: air (1) hydrogen: methane (1)	**2**
3(b)(iii)	**M1** 450 (1) **M2** 20 000 (1) **M3** iron (1)	**3**

Q28 (continued) **0620/42/F/M/23 Q3(a),(b)(iii)-(iv)** Industrial equilibrium processes - Hard

3(b)(iv)	one mark for each of |	decreases
decreases	decreases
	no change		**4**

Q29 **0620/41/M/J/23 Q6(b)** Industrial equilibrium processes - Hard

6(b)(i)	yield of SO_3 is less	**1**
6(b)(ii)	yield of SO_3 is less **OR** rate is less	**1**

Q30 **0620/42/M/J/23 Q3(a)-(b)(v)** Industrial equilibrium processes - Hard

3(a)	contact (process)	**1**
3(b)(i)	M1 burning sulfur (in air) M2 Roasting sulfide ores (in air)	**2**
3(b)(ii)	M1 the rate of forward reaction equals (the rate of the) reverse reaction M2 concentrations of reactants and products are constant	**2**
3(b)(iii)	450 (°C) 200 (kPa) vanadium(V) oxide	**3**
3(b)(iv)	 |	increases
increases	increase
	no change		**4**
3(b)(v)	M1 kinetic energy of particles decreases M2 frequency of collisions between particles decreases M3 lower percentage / proportion / fraction of collisions / particles have energy greater than / qual to activation energy **OR** fewer **of the** collisions / particles have energy greater than / equal to activation energy	**3**

Q31 **0620/41/O/N/21 Q4(b)** Industrial equilibrium processes - Hard

4(b)(i)	**M1** rate of forward reaction = rate of reverse reaction (1) **M2** concentration of reactants and products are constant (1)	**2**
4(b)(ii)	**M1** 450 °C (1) **M2** 1-2 atm (1)	**2**
4(b)(iii)	vanadium(V) oxide	**1**
4(b)(iv)	increase rate of reaction	**1**
4(b)(v)	**M1** equilibrium shifts to left hand side (1) **M2** forward reaction is exothermic (1)	**2**

Q32 **0620/42/O/N/22 Q3(c)-(d)** Industrial equilibrium processes - Hard

3(c)	contact	**1**
3(d)(i)	**M1** 450 (°C) (1) **M2** 1–2 (atm) (1)	**2**
3(d)(ii)	vanadium(V) oxide	**1**
3(d)(iii)	**M1** the rate of forward reaction equals (the rate of the) reverse reaction (1) **M2** concentrations of reactants and products are constant (1)	**2**
3(d)(iv)	*increased temperature:* **M1** (position of) equilibrium moves to left-hand side (1) **M2** reaction is exothermic (1) *increased pressure:* **M3** (position of) equilibrium moves to right-hand side (1) **M4** more (gaseous) moles / molecules on left-hand side (1)	**4**

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Q32 (continued) **0620/42/O/N/22 Q3(c)-(d)** Industrial equilibrium processes - Hard

3(d)(v)	**M1** rate increases **and** particles have more energy (1) **M2** more collisions (between particles) occur per second / per unit time (1) **M3** more of the particles / collisions have energy equal to or above the activation energy (1) **or** more of the particles / collisions have sufficient energy to react **or** a higher percentage / proportion / fraction of collisions (of particles) are successful / have energy equal to or above activation energy	**3**

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