AQA GCSE Chemistry | 8462

SPECIFICATION POINT 4.6.1.4

Catalysts

Past-paper questions

Tier	**Higher**
Question groups	**48**
Available paper years	**2007–2025**

Using this booklet

1. Answer the questions in order and show your working.
2. Original question numbers and marks are retained.
3. Print at actual size (100%) for measuring questions.
4. Use the companion answer booklet to check your work.

Name: _____ **Date:** _____

Whole questions are retained for context, so some parts assess other specification points. Current and legacy sources are labelled. Continue on extra paper if needed.

4.6.1.4 Catalysts

Question 01

March 2007 | CHY1B | Original Q1 | Legacy

QUESTION ONE

The flow chart shows the stages in the breakdown of large hydrocarbon molecules.

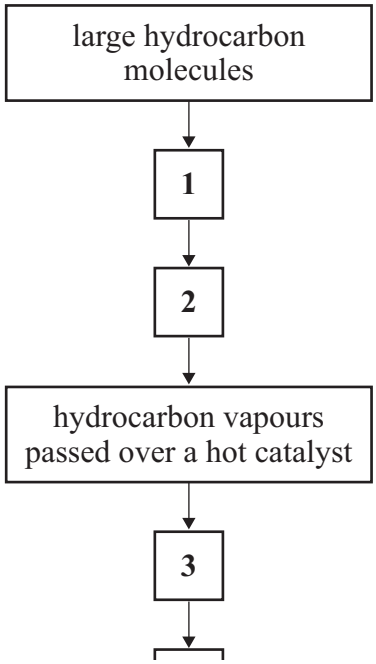
Match phrases, **A**, **B**, **C** and **D**, with the numbers **1–4** in the flow chart.

A hydrocarbons undergo thermal decomposition

B hydrocarbons are heated

C hydrocarbons vaporise

D small hydrocarbon molecules



4.6.1.4 Catalysts

Question 02

June 2007 | CHY1A | Original Q8 | Legacy

QUESTION EIGHT

Exhaust fumes from petrol-driven cars contain harmful gases, particularly acidic nitrogen oxide, poisonous carbon monoxide and unburned hydrocarbons.

Catalytic converters are fitted to these cars to help to reduce the quantities of these gases released into the atmosphere. The reaction in the converter can be summarised by this equation:

carbon monoxide + nitrogen oxide → carbon dioxide + nitrogen

The catalysts in the converters usually contain a mixture of two transition metals, platinum and rhodium.

These metals occur in the Earth's crust mainly with copper and nickel sulfide ores.
To extract the metals, the ores are roasted in air which produces sulfur dioxide.

8A The balanced, symbol equation for the reaction between carbon monoxide and nitrogen oxide is . . .

1 $2CO + 2NO \rightarrow 2CO_2 + N_2$

2 $CO + NO \rightarrow CO_2 + N_2$

3 $2CO + 2NO \rightarrow CO_2 + N_2$

4 $2CO + 2NO \rightarrow CO_2 + 2N_2$

8B Which substance is reduced in this reaction?

1 carbon monoxide

2 carbon dioxide

3 nitrogen oxide

4 nitrogen

8C Why do some environmental organisations question the benefits of catalytic converters?

1 They are expensive to manufacture and make cars more expensive.

2 Polluting gases are released both in producing them and in using them.

3 They do not remove any of the harmful gases from the exhaust fumes.

4 Nitrogen is a poisonous gas.

4.6.1.4 Catalysts

8D What conclusion about the use of catalytic converters can safely be made from the information in this question?

1 Transition metals are good conductors of heat and electricity.

2 There are no harmful gases in the exhaust fumes from a car fitted with a catalytic converter.

3 A catalytic converter reduces the amount of carbon monoxide in the exhaust fumes from a petrol-driven car.

4 Catalytic converters work equally well in both diesel-driven and petrol-driven cars.

Turn over for the next question

4.6.1.4 Catalysts

Question 03

June 2007 | CHY1B | Original Q7 | Legacy

QUESTION SEVEN

A compound, C_4H_{10}, was decomposed by passing it over a hot catalyst.

Analysis showed the product to be a mixture of two different hydrocarbons, hydrocarbon **A** (an alkane) and hydrocarbon **B**.
Both hydrocarbon **A** and hydrocarbon **B** had two carbon atoms in each molecule.

7A Which row in the table shows the correct formulae for these two hydrocarbons?

	Hydrocarbon A	Hydrocarbon B
1	C_2H_6	C_2H_4
2	C_2H_2	C_2H_8
3	C_2H_4	C_2H_6
4	C_2H_5	C_2H_5

7B The boiling point of hydrocarbon **A** is –89 °C and that of hydrocarbon **B** is –104 °C.

They could probably be separated and collected by . . .

1 thermal decomposition.

2 cracking.

3 condensation.

4 polymerisation.

7C Each of the two hydrocarbons was tested with bromine water.

Which row in the table correctly shows what happens to the bromine water?

	With hydrocarbon A	With hydrocarbon B
1	turns green	turns colourless
2	turns colourless	stays yellow-brown
3	stays yellow-brown	turns colourless
4	stays yellow-brown	turns green

4.6.1.4 Catalysts

7D Of these two hydrocarbons, only hydrocarbon **B** can form polymers.

This is because . . .

1 it has a higher boiling point.

2 its molecule has a double carbon carbon bond.

3 its molecule is saturated.

4 it has smaller molecules.

Turn over for the next question

4.6.1.4 Catalysts

Question 04

June 2007 | CHY1H | Original Q5 | Legacy

5 Known crude oil reserves are being used up rapidly. Crude oil is used to produce many useful fuels, such as petrol. One way to conserve crude oil reserves would be to increase the production of bio-fuels.

(a) Ethanol can be produced for use as a bio-fuel. Cars can be powered by ethanol or ethanol–petrol mixtures.

Sugar cane can be fermented to give a mixture of water (boiling point 100 °C) and ethanol (boiling point 78 °C).

(i) How can ethanol be separated from water?

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.....

(1 mark)

(ii) Ethanol, C_2H_5OH, burns to release heat energy.

Complete the balanced symbol equation by writing in the formulae of the two products.

$C_2H_5OH + 3O_2 \rightarrow 2..... + 3.....$

(2 marks)

4.6.1.4 Catalysts

Question 04 · continued

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(b) The cost of producing a bio-fuel, such as ethanol, by fermentation, is at least three times higher than the production cost of petrol. It costs less to produce ethanol from alkanes. In the production, the vapour of an alkane is passed over a hot catalyst.

$$\underset{\text{hexane}}{C_6H_{14}} \xrightarrow{\text{Hot catalyst}} \underset{\text{ethane}}{C_2H_6} + \underset{\text{ethene}}{2C_2H_4}$$

Ethene is then converted into ethanol.

(i) What has happened to the hexane to produce ethene?

.....

(1 mark)

(ii) Complete the structural formula for ethene, C_2H_4.

C **C**

(1 mark)

(iii) Name the compound that is added to ethene to produce ethanol, C_2H_5OH.

.....

(1 mark)

(c) As explained in parts (a) and (b), ethanol can be made using either sugar or alkanes as the starting material.

Evaluate the advantages and disadvantages of using these two starting materials to produce ethanol.

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(4 marks)

10

4.6.1.4 Catalysts

Question 05

June 2008 | CHY1AP | Original Q4 | Legacy

QUESTION FOUR

Scientists are researching new catalysts to convert compounds in coal into small hydrocarbon molecules.

These small molecules can be used to make liquid fuels such as petrol.

4A Scientists are trying to develop processes that convert coal into liquid fuels, such as petrol, because . . .

1 they have found new supplies of catalysts.

2 oil reserves are running out quickly.

3 there is no alternative to using coal.

4 catalysts are being used up.

4B Petrol is made from small molecules and **not** large molecules because hydrocarbons with small molecules . . .

1 have a higher boiling point.

2 are more viscous.

3 are darker in colour.

4 ignite more easily.

4C Both petrol and coal produce carbon dioxide when burned.

To compare the volume of the gas produced by a sample of coal with the volume of gas produced by a sample of petrol, a control variable would be . . .

1 how much carbon dioxide is produced.

2 the amount of coal and petrol used.

3 the speed at which each fuel is set alight.

4 the time taken to burn all the fuel.

4.6.1.4 Catalysts

4D Ethanol, made from plant material, is another liquid fuel used in cars.

Ethanol and petrol produce similar amounts of carbon dioxide when they burn.

Burning ethanol made from plant material, in cars, is thought to be less of an environmental problem than burning petrol.

This is because . . .

1 ethanol does **not** produce water when it burns.

2 using ethanol made from plants as a fuel does **not** change the amount of carbon dioxide in the atmosphere.

3 ethanol will burn without using oxygen.

4 in the car engine, only partial combustion of the ethanol occurs.

Turn over for the next question

4.6.1.4 Catalysts

Question 06

June 2008 | CHY1BP | Original Q1 | Legacy

QUESTION ONE

This question is about unsaturated hydrocarbons.

Match words, **A**, **B**, **C** and **D**, with the numbers **1–4** in the sentences.

A catalysis

B polymerisation

C combustion

D thermal decomposition

Heating large hydrocarbon molecules so that they break down into smaller molecules, such as ethene, is an example of . . . **1** . . . .

Ethanol is formed when ethene reacts with steam. The reaction is speeded up using phosphoric acid. This reaction is an example of . . . **2** . . . .

Individual ethene molecules can be made to link together to form very long chains in a process called . . . **3** . . . .

Ethene reacts with oxygen to produce carbon dioxide and water. This reaction is an example of . . . **4** . . . .

4.6.1.4 Catalysts

Question 07

June 2008 | CHY2H | Original Q8 | Legacy

8 Epoxyethane has the formula C_2H_4O. It is used to make antifreeze and some types of plastic.

When choosing a method of making a chemical, it is important to consider:

- the percentage yield
- the atom economy.

Epoxyethane can be made from ethene by two different methods. The overall equation for each method is shown below.

Method 1

$$\underset{\text{ethene}}{C_2H_4} + Cl_2 + Ca(OH)_2 \rightarrow \underset{\text{epoxyethane}}{C_2H_4O} + CaCl_2 + H_2O$$

Method 2

$$\underset{\text{ethene}}{2C_2H_4(g)} + O_2(g) \overset{\text{catalyst}}{\rightleftharpoons} \underset{\text{epoxyethane}}{2C_2H_4O(g)}$$

8 (a) The table gives the relative formula masses (M_r) of the reactants and products for **Method 1**.

Formula of reactant or product	Relative formula mass (*Mr*)
H_2O	18
C_2H_4	28
C_2H_4O	44
Cl_2	71
$Ca(OH)_2$	74
$CaCl_2$	111

The percentage atom economy can be calculated using:

$$\text{Percentage atom economy} = \frac{M_r \text{ of useful product}}{\text{Total } M_r \text{ of all reactants added together}} \times 100\%$$

The percentage atom economy for **Method 2** is 100%.

4.6.1.4 Catalysts

Question 07 · continued

for mark

8 (a) Calculate the percentage atom economy for **Method 1**.

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(2 marks)

8 (b) **Method 2** has the higher atom economy.

Suggest why this is an advantage.

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(2 marks)

8 (c) State and explain how an increase in pressure would affect the equilibrium yield of epoxyethane using **Method 2**.

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(2 marks)

8 (d) One problem with **Method 2** is that ethene can also react with oxygen to make carbon dioxide and water.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

How might this reaction affect the percentage yield of epoxyethane?

.....

.....

(1 mark)

7

4.6.1.4 Catalysts

Question 08

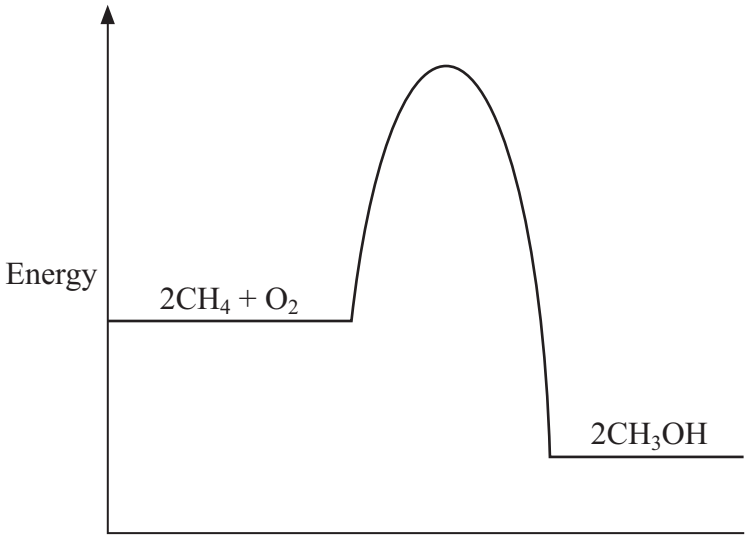
June 2008 | CHY3H | Original Q7 | Legacy

7 Methanol (CH_3OH) can be made by reacting methane (CH_4) and oxygen (O_2) in the presence of a platinum catalyst. The reaction is exothermic.

An equation that represents the reaction is:

$$2CH_4 + O_2 \rightarrow 2CH_3OH$$

7 (a) The energy level diagram for this reaction is given below.



7 (a) (i) Use the diagram to explain how you know that this reaction is exothermic.

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(1 mark)

7 (a) (ii) Explain, in terms of the energy level diagram, how the platinum catalyst increases the rate of this reaction.

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.....

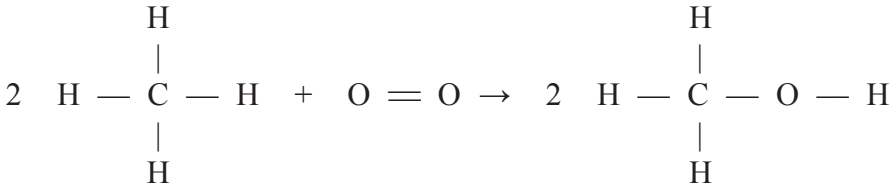
(1 mark)

4.6.1.4 Catalysts

Question 08 · continued

for mark

7 (b) The equation can also be written showing the structural formulae of the reactants and the product.



7 (b) (i) Use the bond energies given in the table to help you to calculate the energy change for this reaction.

Bond	Bond energy in kJ
C — H	435
O = O	498
C — O	805
O — H	464

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Energy change = ... kJ

(3 marks)

7 (b) (ii) In terms of the bond energies, explain why this reaction is exothermic.

.....

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(1 mark)

6

4.6.1.4 Catalysts

Question 09

March 2009 | CHY1BP | Original Q2 | Legacy

QUESTION TWO

This question is about vegetable oils.

Match words, **A**, **B**, **C** and **D**, with the numbers **1–4** in the sentences.

A catalysed

B emulsified

C unsaturated

D hardened

The amount of double carbon carbon bonds in an oil can be estimated by reacting the oil with bromine. If the bromine reacts, this shows the oil to be . . . **1** . . . .

The double carbon carbon bonds in the oil can be removed by heating with hydrogen in the presence of nickel. This is an example of a reaction that has been . . . **2** . . . .

As a result of this reaction with hydrogen, the oil is . . . **3** . . . .

A vegetable oil can be . . . **4** . . . by shaking the oil with water.

4.6.1.4 Catalysts

Question 10

March 2009 | CHY1BP | Original Q6 | Legacy

QUESTION SIX

This question is about cracking large hydrocarbon molecules.

Cracking is achieved by using either a high temperature and pressure without a catalyst, or a low temperature and pressure with a catalyst.

Whichever method is chosen:

- the energy for cracking is provided by burning fossil fuels;
- the zeolite catalysts used are not very expensive;
- the catalyst is not used up in the process;
- the cracking plant is often built near the oil refinery.

6A Which of the following occurs during cracking?

1 Small hydrocarbon molecules join together.

2 The hydrocarbon molecules become saturated.

3 The hydrocarbon molecules react together.

4 The hydrocarbon molecules are decomposed.

6B In which equation do the products include two different alkenes?

1 $C_{15}H_{32} \rightarrow 2C_2H_4 + C_3H_6 + C_8H_{18}$

2 $C_{15}H_{32} \rightarrow C_2H_2 + C_5H_{10} + C_8H_{18} + H_2$

3 $C_{15}H_{32} \rightarrow C_8H_{18} + C_7H_{14}$

4 $C_{15}H_{32} \rightarrow C_7H_{16} + C_8H_{16}$

6C Which of the following shows only products that could be directly obtained by cracking $C_{10}H_{22}$?

1 alkanes up to $C_{20}H_{44}$, hydrogen and ethene

2 alkanes up to C_8H_{18}, carbon dioxide and ethene

3 propene, poly(ethene) and hydrogen

4 alkanes up to C_8H_{18}, ethene and propene

4.6.1.4 Catalysts

Question 10 · continued

6D These are the formulae for three hydrocarbons:

C_2H_4 C_2H_6 C_3H_6

Which row in the table shows the hydrocarbons that could form polymers, and gives the correct reason why they can polymerise?

	Hydrocarbons	Reason
1	C_2H_4 and C_2H_6	their molecules are saturated
2	C_2H_4 and C_3H_6	their molecules have a double carbon carbon bond
3	C_2H_4 and C_3H_6	their molecules are saturated
4	C_2H_4 and C_2H_6	their molecules have a double carbon carbon bond

Turn over for the next question

4.6.1.4 Catalysts

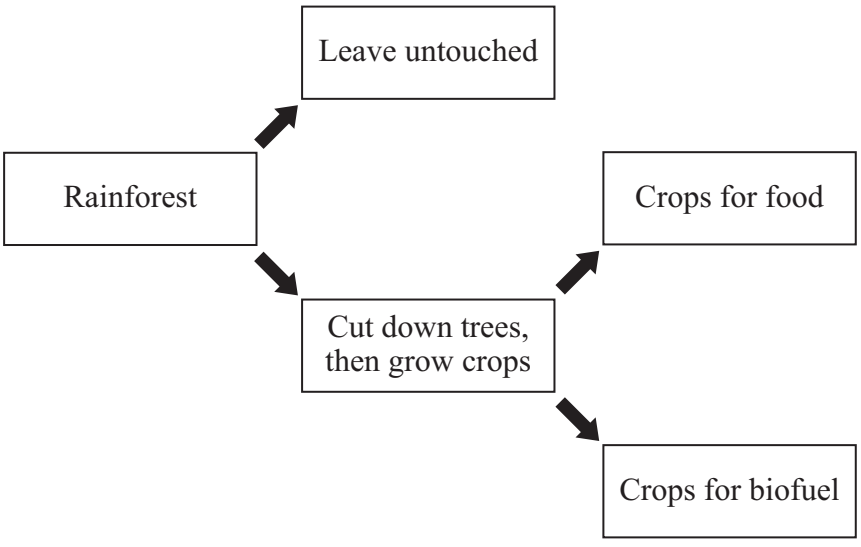
Question 11

June 2009 | CHY1BP | Original Q7 | Legacy

QUESTION SEVEN

Rainforests have an important global role in absorbing carbon dioxide. They are also a habitat for many endangered species.

Many countries have to make difficult decisions about the use of land. This is summarised in the flow chart. Biofuels that are produced include biodiesel and bioethanol. The trees that are cut down are not always replaced.



7A Why is there a large worldwide demand for biofuels?

1 The carbon dioxide produced by the use of the fuel is completely matched by the carbon dioxide taken in when the fuel is grown.

2 They are a renewable source of energy.

3 Their use is always sustained.

4 No greenhouse gases are produced.

Question 11 · continued

7B Which row in the table correctly shows two likely consequences of a long-term increase in the demand for biofuel?

1	fewer crops will be grown for food	more species will be endangered
2	fewer trees in rainforests will be cut down	more land will be used for crops
3	less carbon dioxide will be absorbed by the rainforests	more crops will be grown for food
4	land will not be used and will be returned to rainforest	fossil fuel reserves will run out sooner

7C Scientists have been asked to carry out research to produce evidence about the consequences of developing the use of biofuels.

Which row in the table gives the correct description of an issue and its impact?

	Issue	**Impact**
1	ethical	effect on endangered species
2	social	effect on price of fossil fuels
3	environmental	effect on price of wood
4	economic	effect on levels of oxygen in the atmosphere

7D Some of the vegetable oils grown as a food crop are reacted with hydrogen at 60 °C using a nickel catalyst.

The purpose of this process is to . . .

1 remove single carbon carbon bonds in the oil.

2 add double carbon carbon bonds to the oil.

3 change the oil so that its melting point is higher than room temperature.

4 make the chemicals in the oil detectable with bromine.

4.6.1.4 Catalysts

Question 12

November 2009 | CHY1BP | Original Q7 | Legacy

QUESTION SEVEN

Usually, the lower the melting point of a fat, the more unsaturated it is.

A student measured the melting points of four fats so that he could later compare the amount of unsaturation.

He used four boiling tubes, each half-filled with a different fat. A thermometer was used to measure the melting point of each fat.

The student repeated the measurement of the melting point for each fat either once or twice.

Fat	Melting point in °C		
	Attempt 1	Attempt 2	Attempt 3
Coconut	25	26	
Lard	33	33	
Frying fat	41	49	42
Pastry fat	46	44	

7A Which statement is correct about the way he carried out the test?

1 It was **not** a fair test because he did not repeat each measurement the same number of times.

2 It was a fair test because everything used except the fat, was the same.

3 It was **not** a fair test because he used different fats.

4 It was a fair test because they were all fats.

7B What is the mean value that the student should use for the melting point of frying fat?

1 41.5 °C

2 43.0 °C

3 44.5 °C

4 45.0 °C

4.6.1.4 Catalysts

Question 12 · continued

7C If it is true that the lower the melting point of a fat, the more unsaturated it is, then . . .

1 coconut fat should react with the most bromine in a fair test.

2 pastry fat should react with the most bromine in a fair test.

3 coconut fat should contain the highest number of carbon carbon single bonds.

4 pastry fat should contain the highest number of carbon carbon double bonds.

7D Which row in the table shows the conditions that would be required to harden the coconut oil?

	React with	Temperature in °C	Catalyst
1	oxygen	60	nickel
2	hydrogen	60	nickel
3	hydrogen	100	iron
4	oxygen	100	iron

4.6.1.4 Catalysts

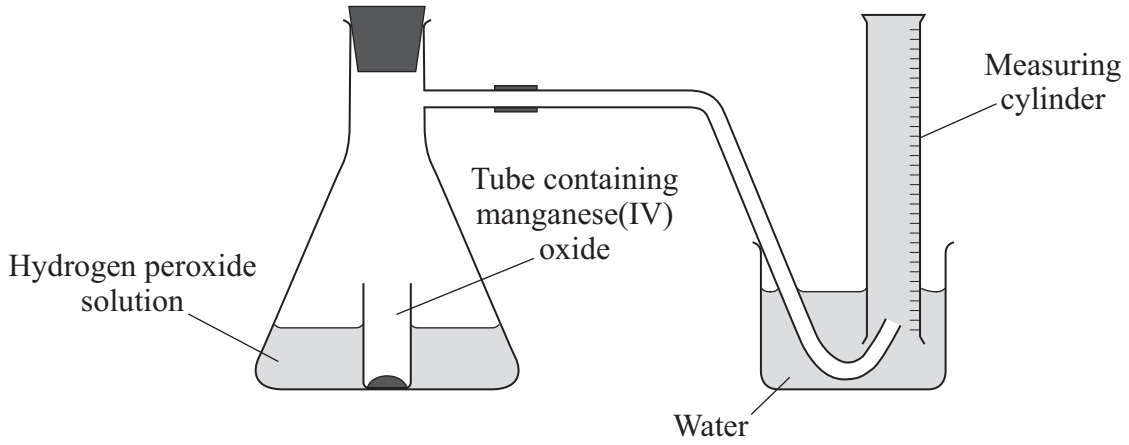
Question 13

January 2010 | CHY2H | Original Q5 | Legacy

5 A student investigated the effect of temperature on the decomposition of hydrogen peroxide. Hydrogen peroxide decomposes to oxygen and water when a manganese(IV) oxide catalyst is added.

The student measured the time taken to collect 5 cm^3 of oxygen gas.

The apparatus shown below was used for the investigation. The reaction was started by shaking the flask so that the manganese(IV) oxide and hydrogen peroxide were mixed.



The student did the investigation at two different temperatures. All the other variables were kept constant.

The student's results are shown in the table.

Temperature of the hydrogen peroxide solution in °C	Volume of oxygen collected in cm^3	Time taken to collect the oxygen in seconds	Rate of reaction in cm^3 per second
20	5	40	0.125
25	5	25	

5 (a) (i) Calculate the rate of reaction at 25 °C.

.....

Rate of reaction = ... cm^3 per second

(2 marks)

5 (a) (ii) The teacher said that the student should repeat the investigation to get more results.

Suggest why.

.....

.....

(1 mark)

4.6.1.4 Catalysts

Question 13 · continued

for mark

5 (b) The student concluded that:

'the rate of reaction increases when the temperature is increased'.

Explain, in terms of particles, why the rate of reaction increases.

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(2 marks)

5

Turn over for the next question

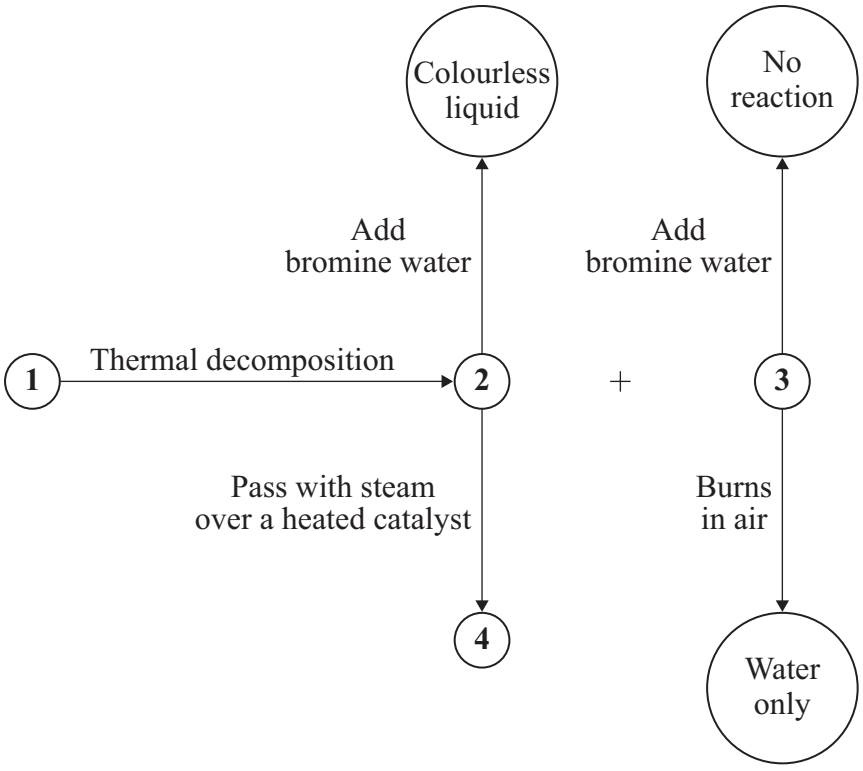
4.6.1.4 Catalysts

Question 14

March 2010 | CHY1BP | Original Q2 | Legacy

QUESTION TWO

The flow chart shows a series of chemical reactions.



Match chemicals, **A**, **B**, **C** and **D**, with the numbers **1–4** in the flow chart.

A Ethane

B Ethene

C Ethanol

D Hydrogen

4.6.1.4 Catalysts

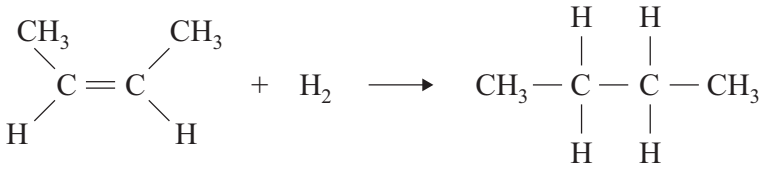
Question 15

March 2010 | CHY1BP | Original Q9 | Legacy

QUESTION NINE

Unsaturated oils contain double carbon carbon bonds. If an unsaturated hydrocarbon is heated with hydrogen gas and a nickel catalyst, the following reaction takes place.

Unsaturated hydrocarbon **Saturated hydrocarbon**



9A What is this process called?

1 cracking

2 polymerisation

3 hydrogenation

4 combustion

9B An unsaturated oil is made into a saturated compound.

The saturated compound . . .

1 contains fewer hydrogen atoms in its molecules.

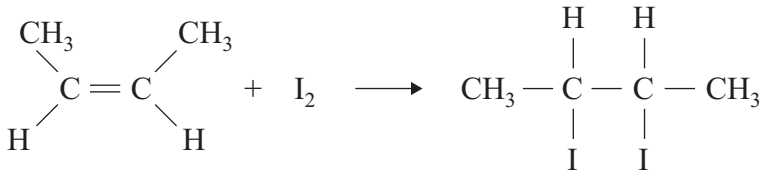
2 has a higher melting point.

3 feels softer but has the same melting point.

4 would be more useful as a fuel for vehicles.

Question 15 · continued

9C Iodine (I_2) reacts with unsaturated hydrocarbons as shown in the equation.



The iodine number is the number of grams of iodine that will react with 100 g of the unsaturated hydrocarbon. The higher the iodine number, the more unsaturated the hydrocarbon is.

3 g of iodine are added to 1 g of a vegetable oil. When the reaction has finished, 1.2 g of iodine are left unreacted.

What is the iodine number of the oil?

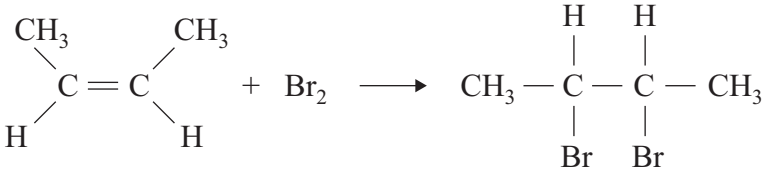
1 120

2 180

3 240

4 300

9D Bromine (Br_2) reacts with unsaturated hydrocarbons in the same way as iodine.



If bromine water is added drop-by-drop to a sample of vegetable oil, the bromine will be decolourised until all the double carbon carbon bonds have reacted.

A sample of an oil with an iodine number of 150 decolourises 25 drops of bromine water. The same amount of another vegetable oil decolourises 6 drops of the same bromine water.

What is the iodine number of the second oil?

1 30

2 36

3 40

4 45

END OF TEST

4.6.1.4 Catalysts

Question 16

June 2010 | CHY2H | Original Q6 | Legacy

6 The equation for a reaction to produce hydrogen is:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

6 (a) Explain why changing the pressure does **not** affect the yield of hydrogen at equilibrium.

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.....

(1 mark)

6 (b) Suggest why the best yield of hydrogen at equilibrium is obtained at **low** temperatures.

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(1 mark)

6 (c) The temperature used in industry needs to be high enough for the reaction to take place quickly. Explain, in terms of particles, why the rate of reaction increases when the temperature is increased.

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(3 marks)

6 (d) Scientists have developed catalysts which allow the reaction to take place quickly at lower temperatures. How could this be good for the manufacturer and for the environment?

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.....

.....

(2 marks)

7

4.6.1.4 Catalysts

Question 17

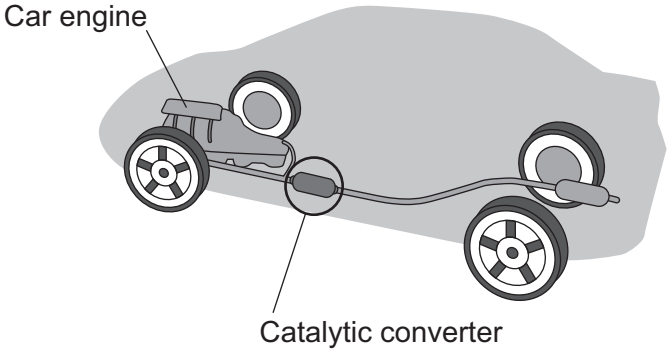
January 2011 | CHY2H | Original Q4 | Legacy

4 Read the information about car engines.

Burning petrol in air is an *exothermic* reaction. This reaction is used in car engines.

When petrol burns it produces harmful substances such as nitrogen oxides and carbon monoxide.

A catalytic converter stops these harmful substances being released into the air.



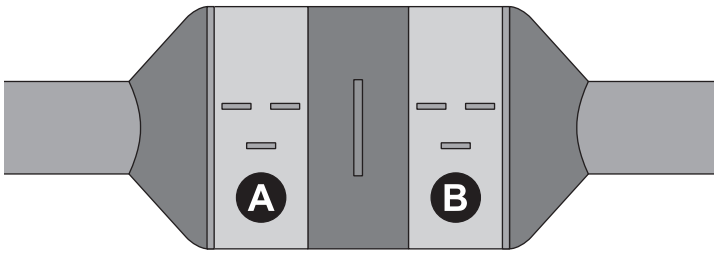
4 (a) The reaction is *exothermic*. What is the meaning of *exothermic*?

.....

.....

(1 mark)

4 (b) The catalytic converter has two parts shown as **A** and **B** in the diagram.



Part **A** contains a catalyst made from platinum and rhodium.

Part **B** contains a catalyst made from platinum and palladium.

4.6.1.4 Catalysts

Question 17 · continued

4 (b) (i) Why are catalysts used in chemical reactions?

.....

.....

(1 mark)

4 (b) (ii) One reaction in part **A** is shown by this equation.

$$2NO \rightarrow N_2 + O_2$$

Suggest why this reaction helps the environment.

.....

.....

(1 mark)

4 (b) (iii) The equation for one of the reactions in part **B** is shown below.

Balance this equation.

..... CO + O_2 → ..... CO_2

(1 mark)

4 (b) (iv) The catalytic converter works for many years without replacing the catalyst.

Explain why the catalyst does not need to be replaced.

.....

.....

(1 mark)

4 (b) (v) Suggest why different catalysts are used in parts **A** and **B**.

.....

.....

(1 mark)

Question 4 continues on the next page

4.6.1.4 Catalysts

Question 17 · continued

4 (c) Modern catalytic converters contain nanosized particles of catalyst. Using nanosized particles reduces the cost of the catalytic converter.

Suggest and explain why the use of nanosized catalyst particles reduces the cost of the catalytic converter.

Your answer should include information about the size and surface area of the particles.

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(3 marks)

9

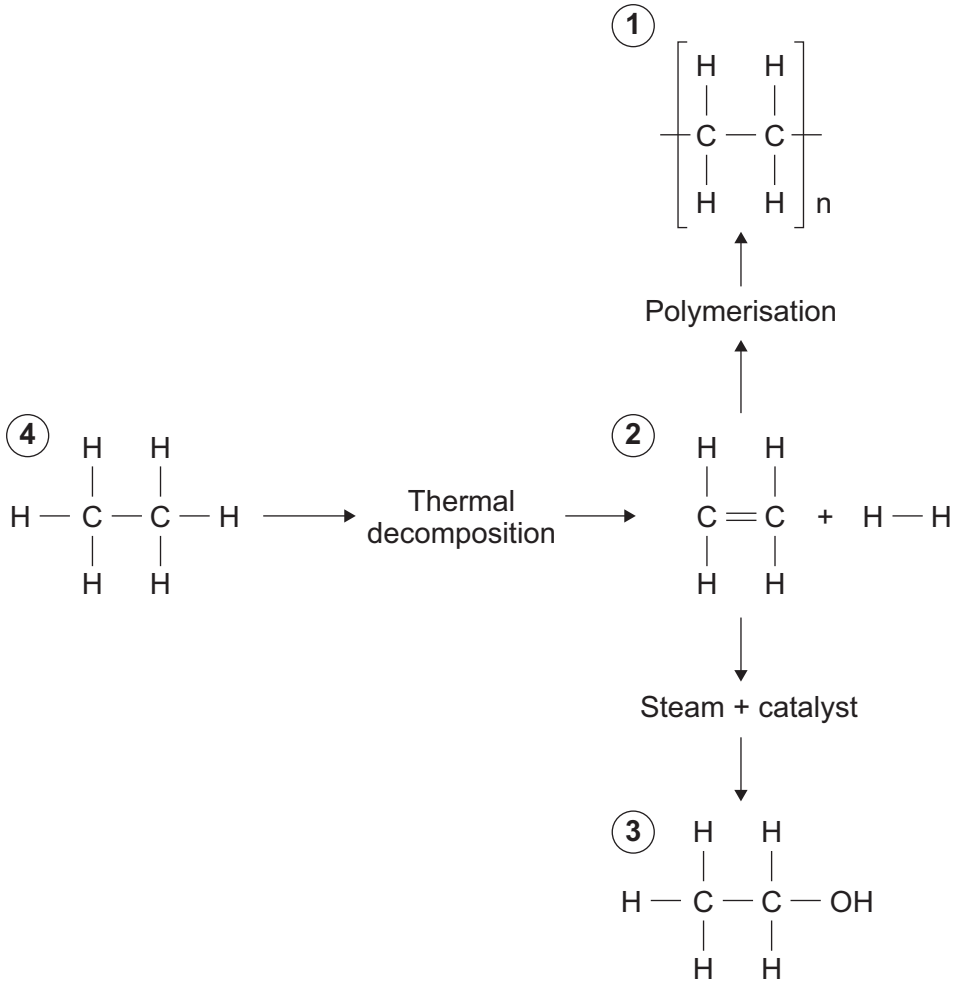
4.6.1.4 Catalysts

Question 18

November 2011 | CHY1BP | Original Q2 | Legacy

QUESTION TWO

The flow chart shows a series of chemical reactions.



Match substances, **A**, **B**, **C** and **D**, with the numbers **1–4** in the flow chart.

A Ethane

B Ethanol

C Ethene

D Poly(ethene)

4.6.1.4 Catalysts

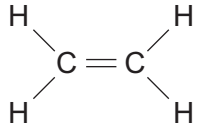
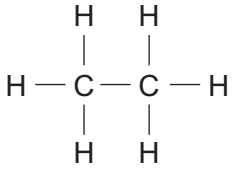
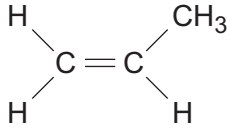
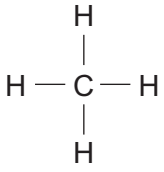
Question 19

November 2011 | CHY1BP | Original Q5 | Legacy

QUESTION FIVE

Polymers have properties that depend on what they are made from and the conditions under which they are made.

5A Which row in the table contains two molecules that are both easily made into polymers?

1	C_3H_6	
2	C_4H_{10}	
3	C_5H_{12}	
4	C_4H_8	

Poly(ethene) was first produced by heating ethene under high pressure and to high temperatures. Later, it was found that poly(ethene) could be produced at much lower temperatures and pressures if an aluminium catalyst was used.

5B An advantage of using a catalyst is that the poly(ethene) could be . . .

1 improved by including aluminium in its structure.

2 manufactured with different alkenes.

3 manufactured by polymerisation of ethane.

4 more economic to produce.

4.6.1.4 Catalysts

Question 19 · continued

5C The poly(ethene) produced using lower temperatures and pressures has a higher density.

This has enabled manufacturers to . . .

1 develop a wider range of products.

2 use different types of monomer to make poly(ethene).

3 use the polymers as fuels.

4 develop products that do not burn.

5D Many products are made using poly(ethene).

Which of the following is likely to be the most environmentally friendly way to deal with these products when they become waste?

1 allow the poly(ethene) to biodegrade

2 put the poly(ethene) in landfill sites

3 burn the poly(ethene) and use the energy released to produce electricity

4 melt the poly(ethene) and make new products

4.6.1.4 Catalysts

Question 20

January 2012 | CH1HP | Original Q7 | Legacy

7 Ethene is used as a starting material for the production of many other substances, including ethanol.

7 (a) Ethene is produced when hydrocarbons are cracked. To do this hydrocarbons are heated to vaporise them. The vapours are then passed over a hot catalyst. The symbol equation shows the reaction for one hydrocarbon.

$$C_{28}H_{58} \rightarrow C_{11}H_{24} + C_{11}H_{22} + C_4H_8 + C_2H_4$$

7 (a) (i) One of the products is a different type of hydrocarbon to the other products.

Complete the sentences.

The formula of the product that is a different type of hydrocarbon is ..... .

The chemical structure of this product is different to the other products because

.....

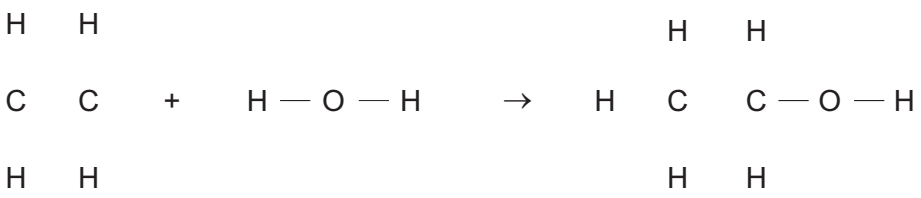
.....

(2 marks)

7 (a) (ii) Ethanol is produced when ethene reacts with steam in the presence of a hot catalyst.

Draw the missing bonds to complete the displayed structures in the equation.

ethene steam ethanol



(2 marks)

7 (b) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

In 1970, the Brazilian Government had stated that all petrol must contain more than 25 % ethanol. The reasons for this statement in 1970 were:

- the oilfields in Brazil at that time only supplied 20 % of the crude oil needed to make petrol
- Brazil has a climate suitable for growing sugar cane.

To produce ethanol the sugar cane plants are crushed and soaked in water for one day. The sugar solution is separated from the plant material by filtration. Yeast is added to the sugar solution and fermented for three days. The yeast is separated from the solution of water and ethanol by filtration. Ethanol is separated from water by fractional distillation.

4.6.1.4 Catalysts

Question 20 · continued

In 2011, the Brazilian Government decided to reduce the amount of ethanol in petrol to 18%. The reasons were that in 2011:

- the demand for ethanol and the price of ethanol had greatly increased
- very large offshore oilfields had been discovered. These offshore oilfields would make Brazil one of the biggest crude oil producers in the world.

Use the information above and your own knowledge and understanding to evaluate whether Brazil should in future produce ethanol from crude oil or produce ethanol from sugar cane.

You should include environmental and economic or social factors in your evaluation.

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(6 marks)

10

4.6.1.4 Catalysts

Question 21

June 2012 | CH1HP | Original Q7 | Legacy

7 Ethanol (C_2H_5OH) is produced from ethene or from sugar cane.

The two different methods to produce ethanol are summarised in the table.

Ethanol from sugar cane is a batch process	Ethanol from crude oil is a continuous process
Sugar cane plants are crushed and soaked in water for one day.	Crude oil is distilled to separate the naphtha fraction.
The sugar solution is separated by filtration.	The naphtha fraction is cracked when the vaporised hydrocarbons are passed over a hot catalyst.
Yeast is added to the sugar solution and fermented for three days.	The ethene produced is separated by distillation.
The solution of water and ethanol produced is separated by filtration.	Ethene is reacted with steam in the presence of a catalyst.
Distillation of this solution produces a 50% solution of ethanol.	This hydration reaction produces 100% ethanol.

7 (a) Complete and balance an equation for the cracking of the hydrocarbon C_6H_{14} to produce ethene.

C_6H_{14} ⟶ ..... + ...

(2 marks)

7 (b) What is **seen** when the sugar solution and yeast are fermented?

.....

.....

(1 mark)

4.6.1.4 Catalysts

Question 21 · continued

7 (c) Evaluate the issues involved with the production of ethanol from sugar cane compared with the production of ethanol from crude oil.
You should explain why each issue you describe is important.

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(5 marks)

8

4.6.1.4 Catalysts

Question 22

June 2012 | CH2HP | Original Q3 | Legacy

3 The symbol equation for the decomposition of hydrogen peroxide is:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

3 (a) This reaction is *exothermic*.

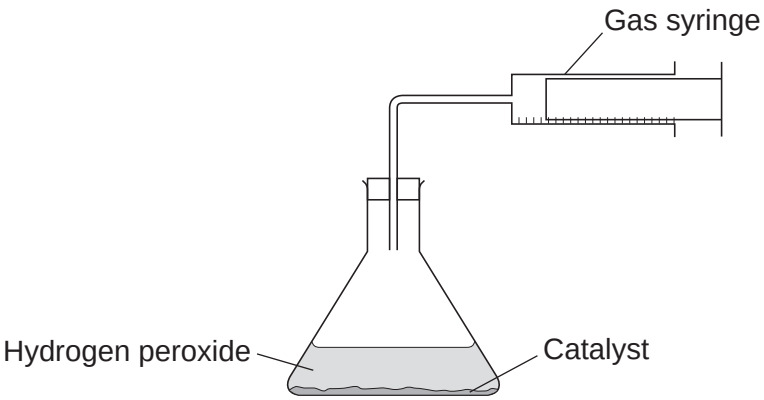
What is an *exothermic* reaction?

.....

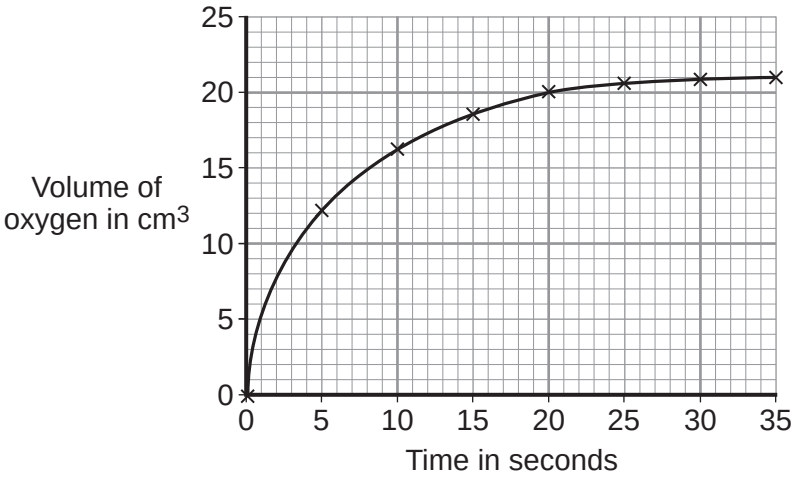
.....

(1 mark)

3 (b) A student measured the volume of oxygen produced by 50 cm^3 of hydrogen peroxide.



The graph shows the results.



4.6.1.4 Catalysts

Question 22 · continued

3 (b) (i) Use the graph to describe the changes in the rate of the reaction from 0 to 35 seconds.

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(3 marks)

3 (b) (ii) What was the total volume of oxygen gas collected? ..... cm^3

(1 mark)

3 (b) (iii) The student had calculated that the hydrogen peroxide used should produce 25 cm^3 of oxygen.

Calculate the percentage yield of oxygen.

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Answer = ... %

(2 marks)

3 (c) An increase in the temperature of the hydrogen peroxide increases the rate of the reaction.

Use your knowledge of particles to explain why.

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(3 marks)

10

4.6.1.4 Catalysts

Question 23

June 2012 | CH2HP | Original Q4 | Legacy

4 This question is about gold (Au).

4 (a) An atom of gold is represented as:

$$^{197}_{79}Au$$

How many neutrons are in this atom of gold? .....

(1 mark)

4 (b) Gold ions are used as a catalyst.

How does a gold atom (Au) become a gold ion (Au^{3+})?

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(2 marks)

4.6.1.4 Catalysts

Question 23 · continued

4 (c) A gold catalyst can be used when carbon monoxide reacts with oxygen to make carbon dioxide.

4 (c) (i) Complete and balance the equation for this reaction.

..... CO + ... → ..... CO_2

(2 marks)

4 (c) (ii) Carbon dioxide has a very low boiling point.

Explain why.

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(3 marks)

4 (d) Gold is used as a catalyst in industrial processes. Gold is rare and increasingly expensive.

Suggest **three** reasons why gold is still used in industrial processes.

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(3 marks)

11

4.6.1.4 Catalysts

Question 24

January 2013 | CH2HP | Original Q4 | Legacy

4 Thermosoftening polymers can be used to make plastic bottles and food packaging.

4 (a) The reaction to produce polymers uses a catalyst.

Why does the catalyst work for a long time before it needs replacing?

.....

.....

(1 mark)

4 (b) Thermosoftening polymers would **not** be suitable for packaging very hot food.

Explain why in terms of their properties and structure.

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(2 marks)

4.6.1.4 Catalysts

Question 24 · continued

4 (c) Compounds from food packaging must not contaminate the food.

Food can be tested for contamination using gas chromatography linked to mass spectroscopy (GC-MS).

4 (c) (i) Gas chromatography can separate substances in a mixture of compounds.

Describe how, as fully as you can.

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(3 marks)

4 (c) (ii) What information does the molecular ion peak give about the molecule?

.....

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(1 mark)

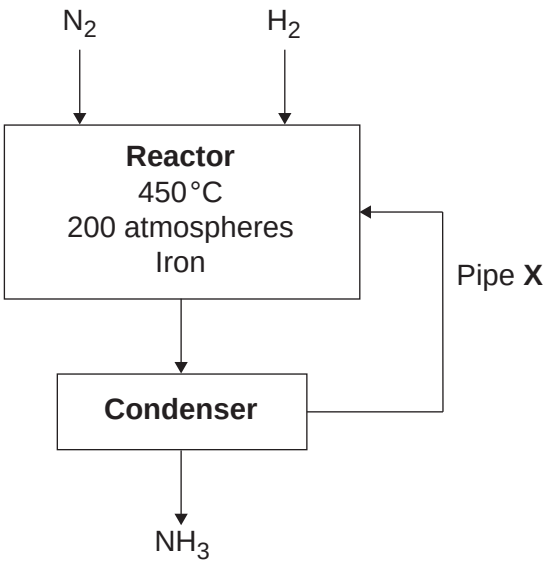
7

4.6.1.4 Catalysts

Question 25

June 2013 | CH3HP | Original Q6 | Legacy

6 The flow diagram shows the Haber process. In the Haber process, ammonia (NH_3) is produced from nitrogen (N_2) and hydrogen (H_2).



6 (a) Which raw material is nitrogen obtained from?

.....

(1 mark)

6 (b) What is the purpose of Pipe **X**?

.....

.....

.....

.....

(2 marks)

6 (c) Balance the chemical equation below for the production of ammonia.

N_2 + ...H_2 $\rightleftharpoons$ .....NH_3

(1 mark)

4.6.1.4 Catalysts

Question 25 · continued

6 (d) A temperature of 450 °C is used in the reactor.
The reaction of nitrogen with hydrogen is reversible.
The forward reaction is exothermic.

Explain why a temperature of 450 °C is the optimum temperature for the Haber process.

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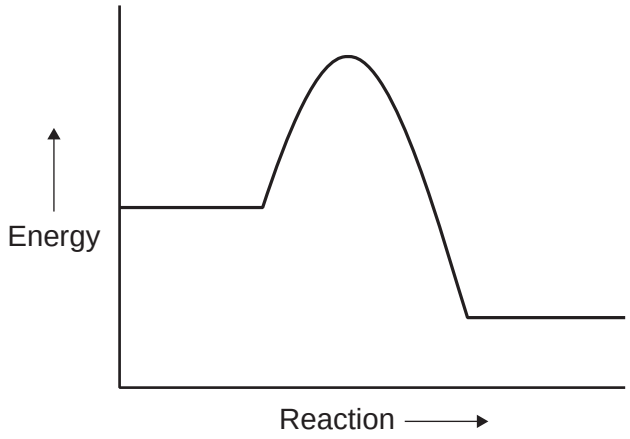
(2 marks)

6 (e) An energy level diagram for the reaction between nitrogen and hydrogen is shown below.



6 (e) (i) How does the energy level diagram show this reaction is exothermic?

.....

.....

(1 mark)

6 (e) (ii) In the Haber process iron is used as a catalyst.

Draw a line on the energy level diagram to show the effect of adding a catalyst.

(1 mark)

8

4.6.1.4 Catalysts

Question 26

June 2014 | CH1HP | Original Q2 | Legacy

2 Ethanol and vegetable oil are used as fuels.

2 (a) There are two different ways to produce ethanol:

- using ethene from crude oil
- using sugar from plants.

2 (a) (i) Ethanol is produced from ethene by **hydration** in the presence of a catalyst.

What is **hydration**?

[1 mark]

.....

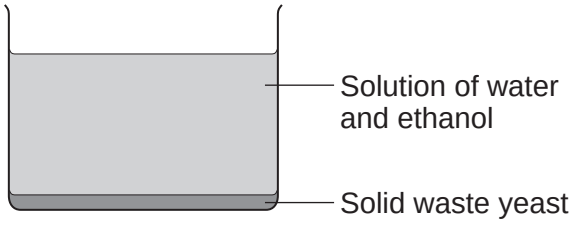
.....

2 (a) (ii) Fermentation is used to produce ethanol from sugar by:

- dissolving the sugar in water
- adding yeast to the sugar solution
- leaving the mixture for three days.

Figure 2 shows the substances after three days.

Figure 2



Suggest:

- how the solid waste yeast is removed
- how ethanol is obtained from the solution.

[2 marks]

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4.6.1.4 Catalysts

Question 26 · continued

2 (b) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

Crude oil is separated to produce the fraction petroleum diesel.

Worries about low supplies of crude oil have led to the growing of large areas of crops to produce vegetable oil.

Vegetable oils are used to produce biodiesel.

There are economic, ethical and environmental issues about the use of biodiesel.

Biodiesel and petroleum diesel are used as a fuel for cars. In a car engine the fuel burns and releases waste products through the car exhaust system.

Table 1 shows the amount of waste products formed by biodiesel compared with the amount of waste products formed by petroleum diesel.

(Note that ppm is parts per million.)

Table 1

	Carbon dioxide in ppm	Nitrogen oxides in ppm	Sulfur dioxide in ppm	Particulates in g per m^3
Biodiesel	20 000	760	0	0.3
Petroleum diesel	80 000	700	300	0.6

Use this information and your knowledge and understanding to give advantages and disadvantages of using biodiesel instead of petroleum diesel.

[6 marks]

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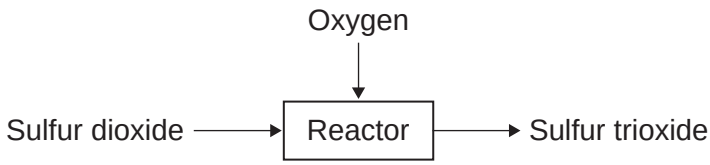
4.6.1.4 Catalysts

Question 27

June 2014 | CH2HP | Original Q3 | Legacy

3 **Figure 2** represents a reaction in the production of sulfuric acid.

Figure 2



3 (a) Complete and balance the equation for the reaction.

[2 marks]

..... $SO_2(g)$ + ... (g) $\rightleftharpoons$ ..... $SO_3(g)$

3 (b) The conditions can affect the rate of the reaction.

3 (b) (i) The pressure of the reacting gases was increased.

State the effect of increasing the pressure on the rate of reaction.

Explain your answer in terms of particles.

[3 marks]

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4.6.1.4 Catalysts

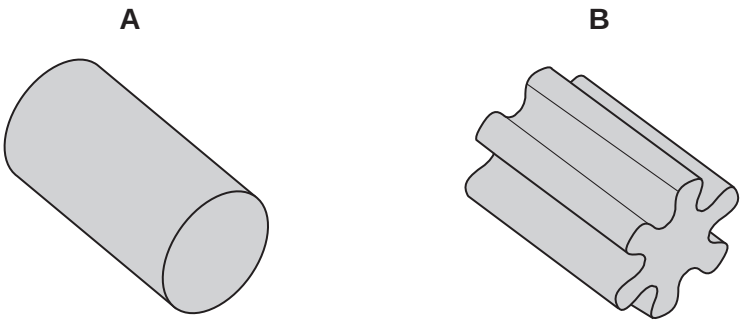
Question 27 · continued

3 (b) (ii) A catalyst is used for the reaction.

The gases pass through a layer containing pieces of the catalyst.

Figure 3 shows the shapes of pieces of catalyst.

Figure 3



Suggest and explain why shape **B** is more effective as a catalyst than shape **A**.

[2 marks]

.....

.....

.....

.....

3 (c) The reaction is carried out at a high temperature to provide the reactants with the **activation energy**.

What is meant by the **activation energy**?

[1 mark]

.....

.....

.....

4.6.1.4 Catalysts

Question 27 · continued

3 (d) Sulfuric acid reacts with metals to produce salts.

3 (d) (i) A student concluded that potassium would **not** be a suitable metal to react with sulfuric acid.

Explain why.

[2 marks]

.....

.....

.....

.....

3 (d) (ii) A student reacted zinc metal with sulfuric acid to produce a salt and another product.

Complete the equation for this reaction.

[2 marks]

$Zn + H_2SO_4 \longrightarrow$ ..... + ...

3 (d) (iii) The student wanted to increase the rate of the reaction between the zinc and sulfuric acid.

State **one** way, other than using a catalyst, that the student could increase the rate of the reaction.

[1 mark]

.....

.....

13

4.6.1.4 Catalysts

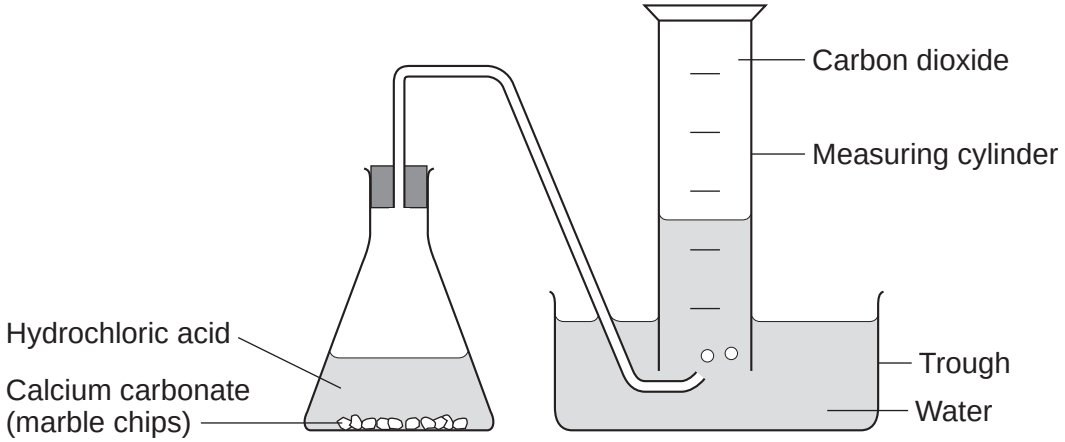
Question 28

June 2015 | CH2HP | Original Q1 | Legacy

1 A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

The student used the apparatus shown in **Figure 1**.

Figure 1



The student:

- recorded the volume of gas collected every 5 seconds
- repeated the experiment using hydrochloric acid at different temperatures.

The equation for the reaction is:

$$CaCO_3(s) + 2\,HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

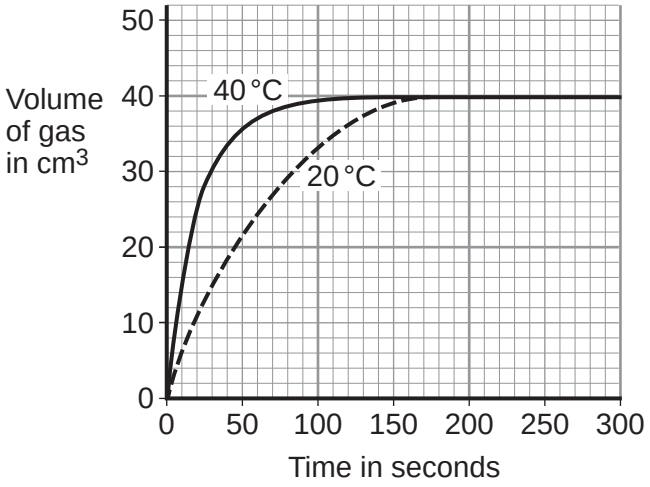
4.6.1.4 Catalysts

Question 28 · continued

1 (a) The student plotted results for the hydrochloric acid at 20 °C and 40 °C on a graph.

Figure 2 shows the student's graph.

Figure 2



Use information from **Figure 2** to answer these questions.

1 (a) (i) State **one** conclusion the student could make about the effect of temperature on the rate of the reaction.

[1 mark]

.....

.....

1 (a) (ii) Give **one** reason why the student could make this conclusion.

[1 mark]

.....

.....

1 (a) (iii) For the hydrochloric acid at 60 °C the student had collected 30 cm^3 after 15 seconds.

Calculate the average rate of reaction from 0 to 15 seconds.

[1 mark]

.....

.....

Rate of reaction = ... cm^3 per second

4.6.1.4 Catalysts

Question 28 · continued

1 (b) The student then investigated how the surface area of marble chips affected the rate of reaction.

1 (b) (i) Which **two** variables should the student keep constant?

[2 marks]

Tick (✓) **two** boxes.

- Amount of water in the trough ☐
- Concentration of acid ☐
- Mass of marble chips ☐
- Size of marble chips ☐
- Volume of measuring cylinder ☐

1 (b) (ii) Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction.

[2 marks]

.....

.....

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.....

1 (c) Calcium carbonate is a catalyst for the industrial production of biodiesel.

Give **one** reason why using a catalyst reduces costs.

[1 mark]

.....

.....

8

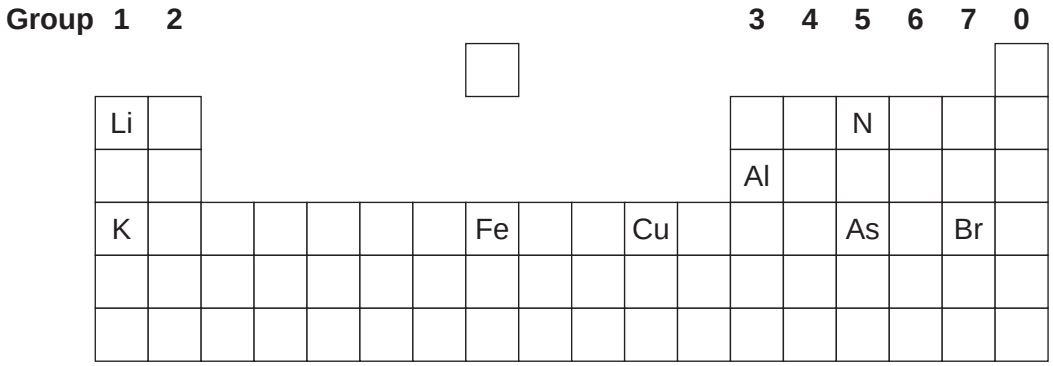
4.6.1.4 Catalysts

Question 29

June 2015 | CH3HP | Original Q1 | Legacy

1 **Figure 1** shows the positions of eight elements in the modern periodic table.

Figure 1



Choose the correct chemical symbols from **Figure 1** to complete each sentence.

1 (a) The **two** metals that react vigorously with water are ..... and ..... .

[1 mark]

1 (b) The element used as a catalyst in the Haber process is ..... .

[1 mark]

1 (c) The **two** elements with five electrons in their outer shell (highest energy level) are

..... and ..... .

[1 mark]

1 (d) Iron has ions with different charges.

The other metal that has ions with different charges is ..... .

[1 mark]

4

4.6.1.4 Catalysts

Question 30

June 2015 | CH3HP | Original Q5 | Legacy

5 This question is about organic compounds.

5 (a) Ethanol is an alcohol.
One use of ethanol is in alcoholic drinks.

Give **two** other uses of ethanol.

[2 marks]

.....

.....

5 (b) Which gas is produced when sodium reacts with ethanol?

[1 mark]

Tick (✓) **one** box.

Carbon dioxide ☐

Carbon monoxide ☐

Hydrogen ☐

Oxygen ☐

5 (c) Ethanoic acid (CH_3COOH) can be produced from ethanol (CH_3CH_2OH).

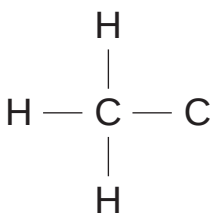
5 (c) (i) What type of reaction produces ethanoic acid from ethanol?

[1 mark]

.....

5 (c) (ii) Complete the displayed structure of ethanoic acid.

[1 mark]



4.6.1.4 Catalysts

Question 30 · continued

5 (c) (iii) Solutions of ethanoic acid and hydrochloric acid with the same concentration have different pH values.

Explain why the solution of ethanoic acid has a higher pH than the solution of hydrochloric acid.

[2 marks]

.....

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5 (d) Ethanol and ethanoic acid react in the presence of a catalyst to form an ester.

5 (d) (i) Name the ester made from ethanol and ethanoic acid.

[1 mark]

.....

5 (d) (ii) What type of chemical is used as a catalyst in this reaction?

[1 mark]

.....

5 (d) (iii) Esters are used in perfumes because they smell pleasant and are volatile.

What does volatile mean?

[1 mark]

.....

10

4.6.1.4 Catalysts

Question 31

June 2015 | CH3HP | Original Q6 | Legacy

6 This question is about reversible reactions and chemical equilibrium.

6 (a) Reversible reactions can reach equilibrium in a closed system.

6 (a) (i) What is meant by a closed system?

[1 mark]

.....

.....

6 (a) (ii) Explain why, when a reversible reaction reaches equilibrium, the reaction appears to have stopped.

[2 marks]

.....

.....

.....

.....

4.6.1.4 Catalysts

Question 31 · continued

6 (b) In the Haber process, the reaction of nitrogen with hydrogen to produce ammonia is reversible.

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

6 (b) (i) Name a natural resource from which hydrogen is produced.

[1 mark]

.....

6 (b) (ii) The Haber process uses a catalyst to speed up the reaction.

Explain how a catalyst speeds up a reaction.

[2 marks]

.....

.....

.....

.....

6 (b) (iii) What happens to the amount of ammonia produced at equilibrium if the pressure is increased?

Give a reason for your answer.

[2 marks]

.....

.....

.....

.....

Question 6 continues on the next page

4.6.1.4 Catalysts

Question 31 · continued

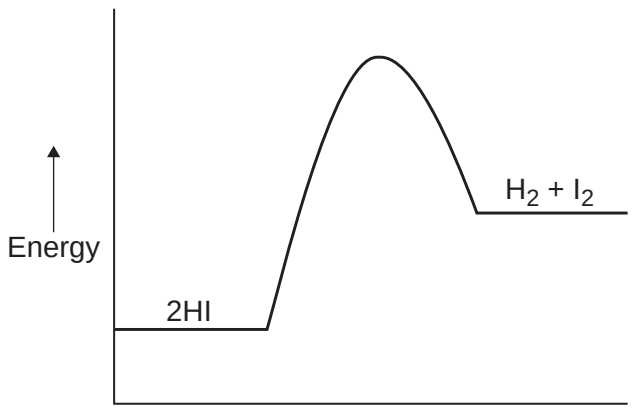
6 (c) The decomposition of hydrogen iodide into hydrogen and iodine is reversible.

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

The forward reaction is endothermic.

The energy level diagram in **Figure 3** is for the forward reaction.

Figure 3



6 (c) (i) Draw an arrow to show the activation energy on the diagram in **Figure 3**.

[1 mark]

4.6.1.4 Catalysts

Question 31 · continued

6 (c) (ii) How does the diagram in **Figure 3** show that the reaction is endothermic?

[1 mark]

.....

.....

6 (c) (iii) Suggest what effect, if any, increasing the temperature will have on the amount of hydrogen iodide at equilibrium.

Give a reason for your answer.

[2 marks]

.....

.....

.....

.....

12

4.6.1.4 Catalysts

Question 32

June 2016 | CH2HP | Original Q3 | Legacy

3 This question is about atoms, molecules and nanoparticles.

3 (a) Different atoms have different numbers of sub-atomic particles.

3 (a) (i) An oxygen atom can be represented as $^{16}_{8}O$

Explain why the mass number of this atom is 16.

You should refer to the numbers of sub-atomic particles in the nucleus of the atom.

[2 marks]

3 (a) (ii) Explain why $^{12}_{6}C$ and $^{14}_{6}C$ are isotopes of carbon.

You should refer to the numbers of sub-atomic particles in the nucleus of each isotope.

[3 marks]

4.6.1.4 Catalysts

Question 32 · continued

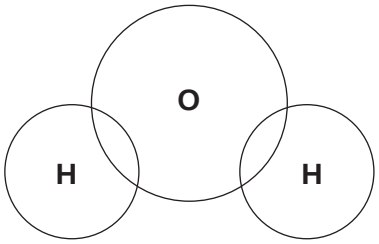
3 (b) Hydrogen atoms and oxygen atoms chemically combine to produce water molecules.

3 (b) (i) Complete **Figure 3** to show the arrangement of the outer shell electrons of the hydrogen and oxygen atoms in a molecule of water.

Use dots (•) or crosses (×) to represent the electrons.

[2 marks]

Figure 3



3 (b) (ii) Name the type of bonding in a molecule of water.

[1 mark]

_____

3 (b) (iii) Why does pure water **not** conduct electricity?

[1 mark]

_____

_____

3 (c) Nanoparticles of cobalt oxide can be used as catalysts in the production of hydrogen from water.

3 (c) (i) How does the size of a nanoparticle compare with the size of an atom?

[1 mark]

_____

_____

3 (c) (ii) Suggest **one** reason why 1 g of cobalt oxide nanoparticles is a better catalyst than 1 g of cobalt oxide powder.

[1 mark]

_____

_____

4.6.1.4 Catalysts

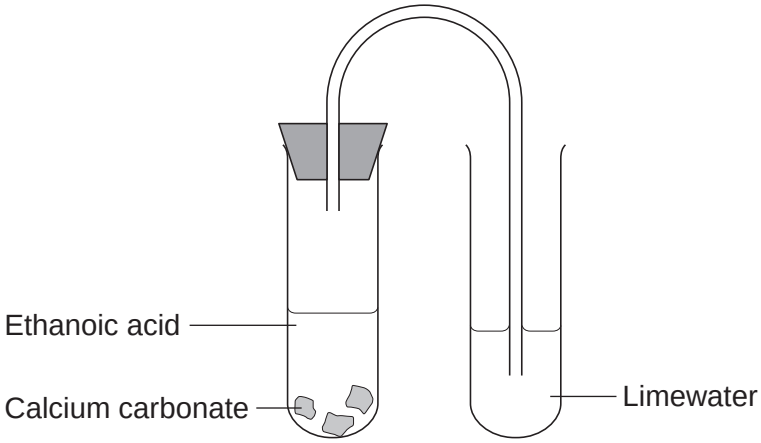
Question 33

June 2016 | CH3HP | Original Q1 | Legacy

1 This question is about reactions of ethanoic acid and the analysis of salts.

1 (a) **Figure 1** shows the apparatus used to investigate the reaction of ethanoic acid with calcium carbonate.

Figure 1



1 (a) (i) Describe a change that would be seen in each test tube.

Give a reason for each change.

[4 marks]

Test tube 1 _____

_____

_____

_____

Test tube 2 _____

_____

_____

_____

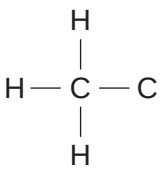
Question 1 continues on the next page

4.6.1.4 Catalysts

Question 33 · continued

1 (a) (ii) Complete the displayed structure of ethanoic acid.

[1 mark]



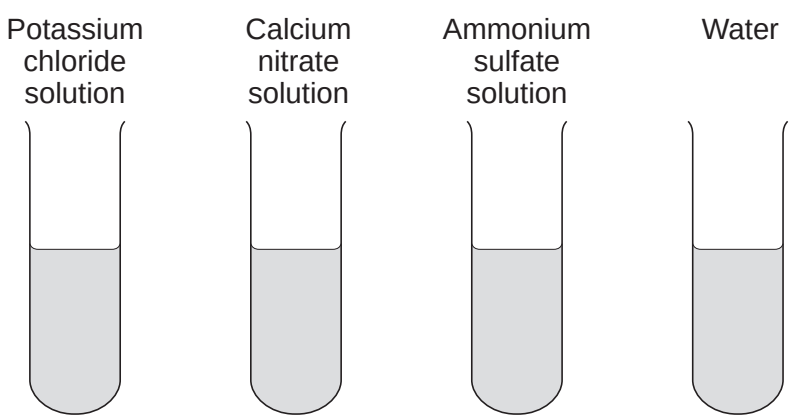
1 (a) (iii) Ethanoic acid is a carboxylic acid.
Complete the sentence.

[2 marks]

Carboxylic acids react with alcohols in the presence of an _____ catalyst to produce pleasant-smelling compounds called _____ .

1 (b) **Figure 2** shows four test tubes containing three different salt solutions and water.

Figure 2



Each solution and the water was tested with:

- silver nitrate in the presence of dilute nitric acid
- barium chloride in the presence of dilute hydrochloric acid.

4.6.1.4 Catalysts

Question 33 · continued

Complete the table of results.

[2 marks]

	Potassium chloride solution	Calcium nitrate solution	Ammonium sulfate solution	Water
Test with silver nitrate in the presence of dilute nitric acid			no change	no change
Test with barium chloride in the presence of dilute hydrochloric acid		no change	white precipitate	

1 (c) Flame tests can be used to identify metal ions.

1 (c) (i) Complete the following sentences.

[2 marks]

The flame colour for potassium ions is _____ .

The flame colour for calcium ions is _____ .

1 (c) (ii) Give **one** reason why a flame test would **not** show the presence of both potassium ions and calcium ions in a mixture.

[1 mark]

_____

_____

_____

12

4.6.1.4 Catalysts

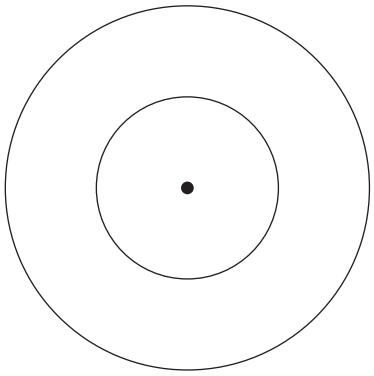
Question 34

June 2017 | CH1HP | Original Q2 | Legacy

2 This question is about compounds of carbon.

2 (a) **Figure 2** shows an atom with two energy levels (shells).

Figure 2



2 (a) (i) A carbon atom has six electrons.

Complete **Figure 2** to show the electronic structure of a carbon atom.

Use **x** to represent an electron.

[1 mark]

2 (a) (ii) Complete the following description about the central part of this carbon atom.

[3 marks]

The central part is made up of six neutrons that have no electrical charge and _____

_____

_____

_____

_____

2 (b) Crude oil is a mixture of compounds. These compounds are mainly hydrocarbons.

What does the term hydrocarbon mean?

[1 mark]

_____

_____

Question 34 · continued

2 (c) Alkanes and alkenes are hydrocarbons.

Table 2 shows the boiling points of some alkanes and alkenes.

Table 2

Alkanes

Name	Formula	Boiling point in °C
Ethane	C_2H_6	−88
Propane	C_3H_8	−42
Butane	C_4H_{10}	0
Pentane	C_5H_{12}	+36
Hexane	C_6H_{14}	+69

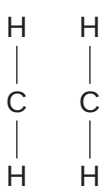
Alkenes

Name	Formula	Boiling point in °C
Ethene	C_2H_4	−104
Propene	C_3H_6	−48
Butene	C_4H_8	−6
Pentene	C_5H_{10}	+30
Hexene	C_6H_{12}	+64

2 (c) (i) Complete the displayed structure of ethane and the displayed structure of ethene.

[2 marks]

Ethane



Ethene



2 (c) (ii) Describe the relationship between the number of carbon atoms in an alkane molecule and the boiling point of the alkane molecule.

[1 mark]

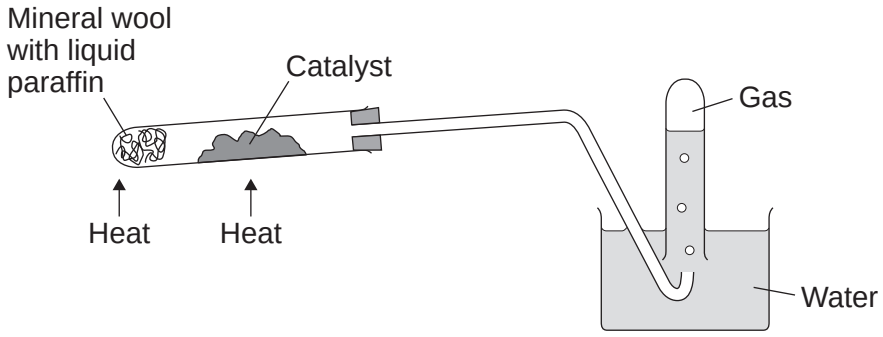
Question 34 · continued

2 (c) (iii) Use the information in **Table 2** to compare the boiling points of alkanes with the boiling points of alkenes.

[2 marks]

2 (d) A student used the apparatus in **Figure 3** to investigate what happens when liquid paraffin is heated to a high temperature.

Figure 3



Liquid paraffin contains alkanes.

Describe what happens to the alkane molecules in this investigation.

[3 marks]

13

4.6.1.4 Catalysts

Question 35

June 2017 | CH1HP | Original Q6 | Legacy

6 Oils from plants are used in the production of fuels and foods.

6 (a) Explain **one** advantage of using biodiesel made from plant oils compared with using fossil diesel made from crude oil.

[2 marks]

6 (b) Plant oils are used in emulsions to give a consistent texture to many foods.

Explain how an emulsion of water and oil is formed.

[4 marks]

6 (c) Bromine water changes colour when shaken with some plant oils.

Describe the colour change.

[2 marks]

Question 6 continues on the next page

4.6.1.4 Catalysts

Question 35 · continued

6 (d) Describe and explain what happens to plant oils when they react with hydrogen in the presence of a nickel catalyst at about 60 °C.

[3 marks]

11

4.6.1.4 Catalysts

Question 36

June 2017 | CH2HP | Original Q1 | Legacy

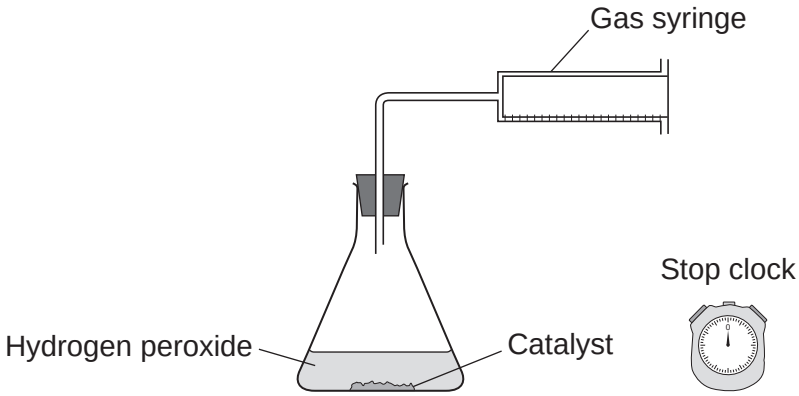
1 This question is about rates of reaction.

The equation for the decomposition of hydrogen peroxide is:

$$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$$

Figure 1 shows the apparatus a student used to investigate the rate of reaction for the decomposition of hydrogen peroxide.

Figure 1



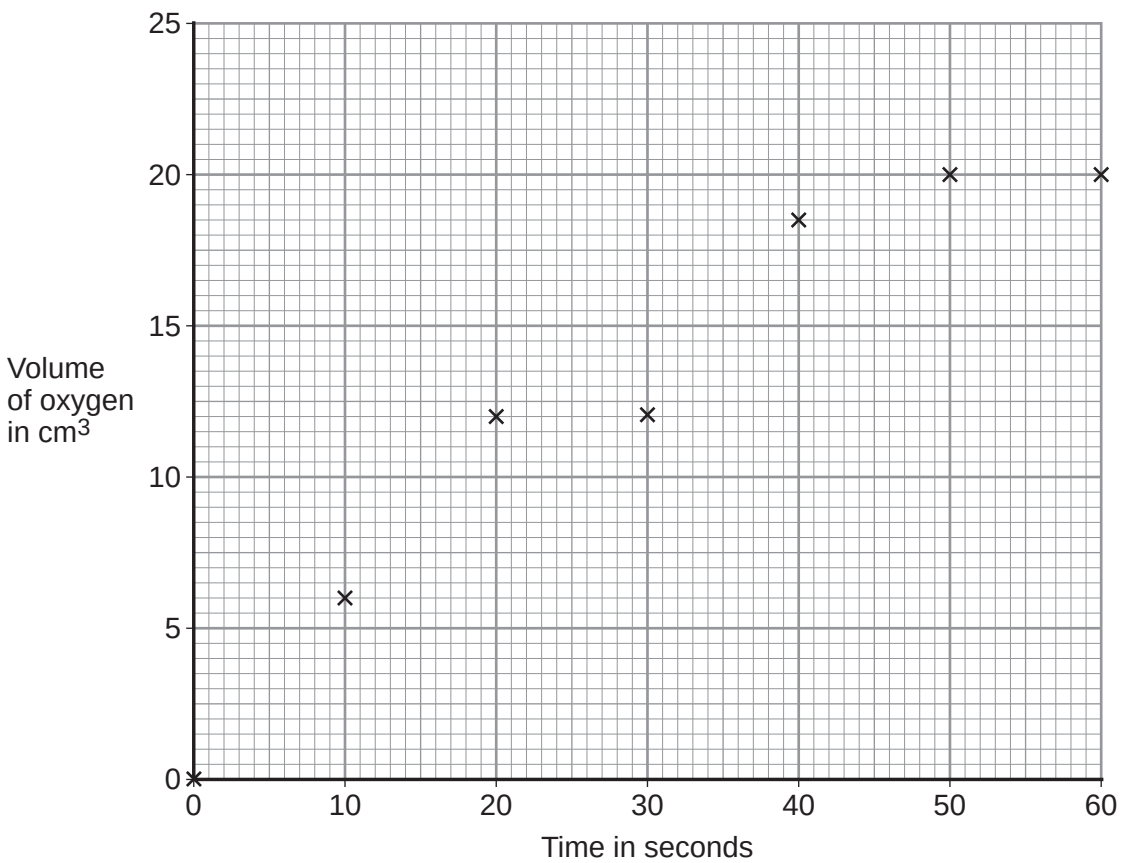
Question 1 continues on the next page

4.6.1.4 Catalysts

Question 36 · continued

The graph in **Figure 2** shows the results.

Figure 2



1 (a) (i) Draw a smooth curve of best fit on **Figure 2**.

[1 mark]

1 (a) (ii) Give the volume of oxygen produced at 25 seconds.

[1 mark]

Volume of oxygen = _____ cm^3

1 (a) (iii) After how many seconds does the reaction stop?

[1 mark]

Time = _____ seconds

4.6.1.4 Catalysts

Question 36 · continued

1 (a) (iv) The student concluded that the rate of reaction decreases with time.

Explain how the results support this conclusion.

[2 marks]

1 (a) (v) Calculate the mean rate of reaction during the first 10 seconds.

[1 mark]

Mean rate of reaction = _____ cm^3 per second

1 (b) The student investigated the effect of concentration on the rate of the reaction.

The student repeated the experiment with greater concentrations of hydrogen peroxide.

1 (b) (i) The catalyst was kept the same. Give **two** other control variables.

[2 marks]

Question 1 continues on the next page

4.6.1.4 Catalysts

Question 36 · continued

1 (b) (ii) State and explain, in terms of particles and collisions, how a greater concentration affects the rate of the reaction.

[3 marks]

1 (c) Describe how increasing the amount of catalyst affects the results in **Figure 2**.

[2 marks]

13

4.6.1.4 Catalysts

Question 37

June 2018 | 8462/2H | Original Q7

0 7 Older cars are tested each year to measure the amount of pollutants contained in exhaust fumes.

Table 4 shows the maximum allowed percentages of exhaust pollutants for petrol cars.

Table 4

Age of car in years	Maximum allowed percentage (%) of exhaust pollutant	
	Carbon monoxide	Unburned hydrocarbons
16–24	0.30	0.02
3–16	0.20	0.02

0 7 . 1 Explain how carbon monoxide is produced when petrol is burned in car engines.

[2 marks]

0 7 . 2 Suggest **two** reasons why the maximum allowed percentage of carbon monoxide has been decreased for newer cars.

[2 marks]

1

2

4.6.1.4 Catalysts

Question 37 · continued

0 7 . 3 Give **one** reason for having a maximum allowed percentage of unburned hydrocarbons in exhaust fumes.

[1 mark]

Oxides of nitrogen are also pollutants contained in exhaust fumes.

0 7 . 4 Describe how oxides of nitrogen are produced when petrol is burned in car engines.

[2 marks]

Catalytic converters are fitted to car exhausts to reduce the amount of pollutants released into the atmosphere.

0 7 . 5 Nitrogen dioxide is an oxide of nitrogen.

Nitrogen dioxide reacts to produce nitrogen and oxygen in catalytic converters.

Complete the equation for this reaction.

The equation should be balanced.

[2 marks]

$$___\ NO_2\ (g) \rightarrow _____ + ___\ O_2\ (g)$$

4.6.1.4 Catalysts

Question 37 · continued

0 7 . 6 Give **two** effects of atmospheric pollution which are reduced by using catalytic converters.

[2 marks]

1 _____

_____

2 _____

_____

0 7 . 7 The catalyst in catalytic converters is a mixture of three elements.

Where in the periodic table are these elements most likely to be found?

[1 mark]

Tick **one** box.

- Alkali metals ☐
- Halogens ☐
- Noble gases ☐
- Transition metals ☐

12

4.6.1.4 Catalysts

Question 38

June 2018 | 8462/2H | Original Q9

0 9 This question is about methanol.

0 9 . 1 Methanol is broken down in the body during digestion.

What type of substance acts as a catalyst in this process?

[1 mark]

Tick **one** box.

- Amino acid ☐
- Enzyme ☐
- Ester ☐
- Nucleotide ☐

In industry, methanol is produced by reacting carbon monoxide with hydrogen.

The equation for the reaction is:

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

0 9 . 2 How many moles of carbon monoxide react completely with 4.0×10^3 moles of hydrogen?

[1 mark]

Tick **one** box.

- 1.0×10^3 moles ☐
- 2.0×10^3 moles ☐
- 4.0×10^3 moles ☐
- 8.0×10^3 moles ☐

4.6.1.4 Catalysts

Question 38 · continued

0 9 . 3 The reaction is carried out at a temperature of 250 ºC and a pressure of 100 atmospheres.

The forward reaction is exothermic.

Explain what happens to the yield of methanol if a temperature higher than 250 ºC is used.

[2 marks]

0 9 . 4 A pressure of 100 atmospheres is used instead of atmospheric pressure.

The higher pressure gives a greater yield of methanol **and** an increased rate of reaction.

Explain why.

[4 marks]

Question 9 continues on the next page

4.6.1.4 Catalysts

Question 38 · continued

A catalyst is used in the reaction to produce methanol from carbon monoxide and hydrogen.

0 9 . 5 Explain how a catalyst increases the rate of a reaction.

[2 marks]

0 9 . 6 Suggest why a catalyst is used in this industrial process.

Do **not** give answers in terms of increasing the rate of reaction.

[1 mark]

0 9 . 7 Suggest the effect of using the catalyst on the equilibrium yield of methanol.

[1 mark]

12

4.6.1.4 Catalysts

Question 39

June 2019 | 8462/1H | Original Q5

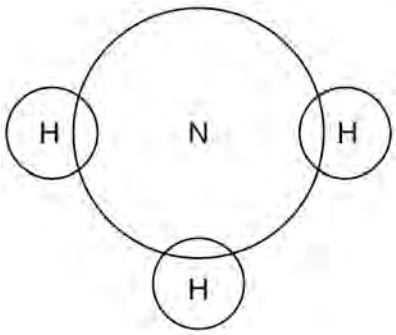
0 5 This question is about ammonia, NH_3

0 5 . 1 Complete the dot and cross diagram for the ammonia molecule shown in **Figure 6**.

Show only the electrons in the outer shell of each atom.

[2 marks]

Figure 6



0 5 . 2 Give **one** limitation of using a dot and cross diagram to represent an ammonia molecule.

[1 mark]

0 5 . 3 Explain why ammonia has a low boiling point.

You should refer to structure and bonding in your answer.

[3 marks]

Question 39 · continued

Ammonia reacts with oxygen in the presence of a metal oxide catalyst to produce nitrogen and water.

0 5 . 4 Which metal oxide is most likely to be a catalyst for this reaction?

[1 mark]

Tick (✓) **one** box.

- CaO ☐
- Cr_2O_3 ☐
- MgO ☐
- Na_2O ☐

Figure 7 shows the displayed formula equation for the reaction.

Figure 7

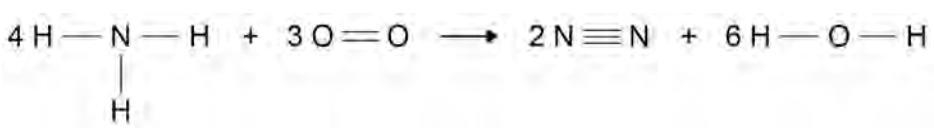


Table 3 shows some bond energies.

Table 3

Bond	N — H	O = O	N ≡ N	O — H
Bond energy in kJ/mol	391	498	945	464

4.6.1.4 Catalysts

Question 39 · continued

0 5 . 5 Calculate the overall energy change for the reaction.

Use **Figure 7** and **Table 3**.

[3 marks]

Overall energy change = _____ kJ

0 5 . 6 Explain why the reaction between ammonia and oxygen is exothermic.

Use values from your calculation in Question **05.5**

[2 marks]

Question 5 continues on the next page

4.6.1.4 Catalysts

Question 39 · continued

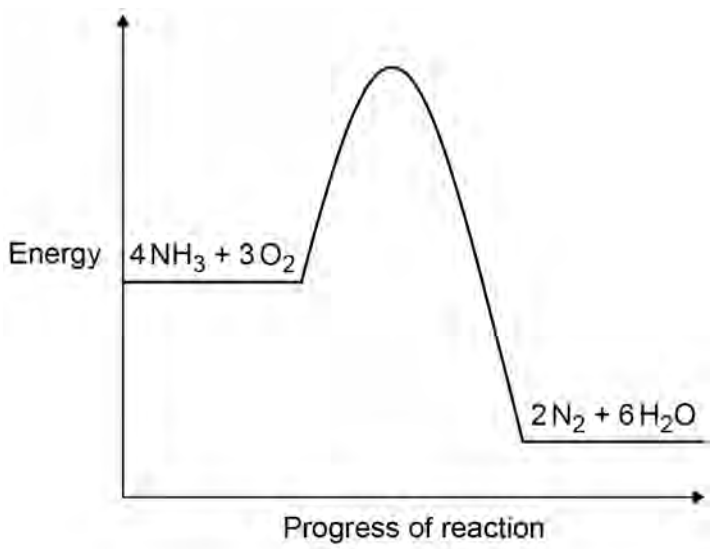
0 5 . 7 **Figure 8** shows the reaction profile for the reaction between ammonia and oxygen.

Complete **Figure 8** by labelling the:

- activation energy
- overall energy change.

[2 marks]

Figure 8



14

4.6.1.4 Catalysts

Question 40

June 2019 | 8462/2H | Original Q9

0 9 Some students investigated the rate of decomposition of hydrogen peroxide, H_2O_2

The equation for the reaction is:

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

The catalyst for the reaction is manganese dioxide.

0 9 . 1 Describe a test to identify the gas produced in the reaction.

Give the result of the test.

[2 marks]

Test _____

_____

Result _____

_____

4.6.1.4 Catalysts

Question 40 · continued

Student **A** investigated the effect of the particle size of manganese dioxide on the rate of the reaction.

This is the method used.

1. Measure 25 cm^3 of 0.3 mol/dm^3 hydrogen peroxide solution into a conical flask.

2. Add a spatula of fine manganese dioxide powder to the conical flask.

3. Measure the volume of gas produced every minute for 10 minutes.

4. Repeat steps 1 to 3 with some coarse manganese dioxide lumps.

0 9 . 2 The method student **A** used did **not** give valid results.

What **two** improvements could student **A** make to the method to give valid results?

[2 marks]

Tick (✓) **two** boxes.

- Measure the increase in mass of the conical flask and contents. ☐
- Measure the volume of gas produced every 2 minutes. ☐
- Place the conical flask in a water bath at constant temperature. ☐
- Use 0.05 mol/dm^3 hydrogen peroxide solution. ☐
- Use a mass of 1 g manganese dioxide each time. ☐

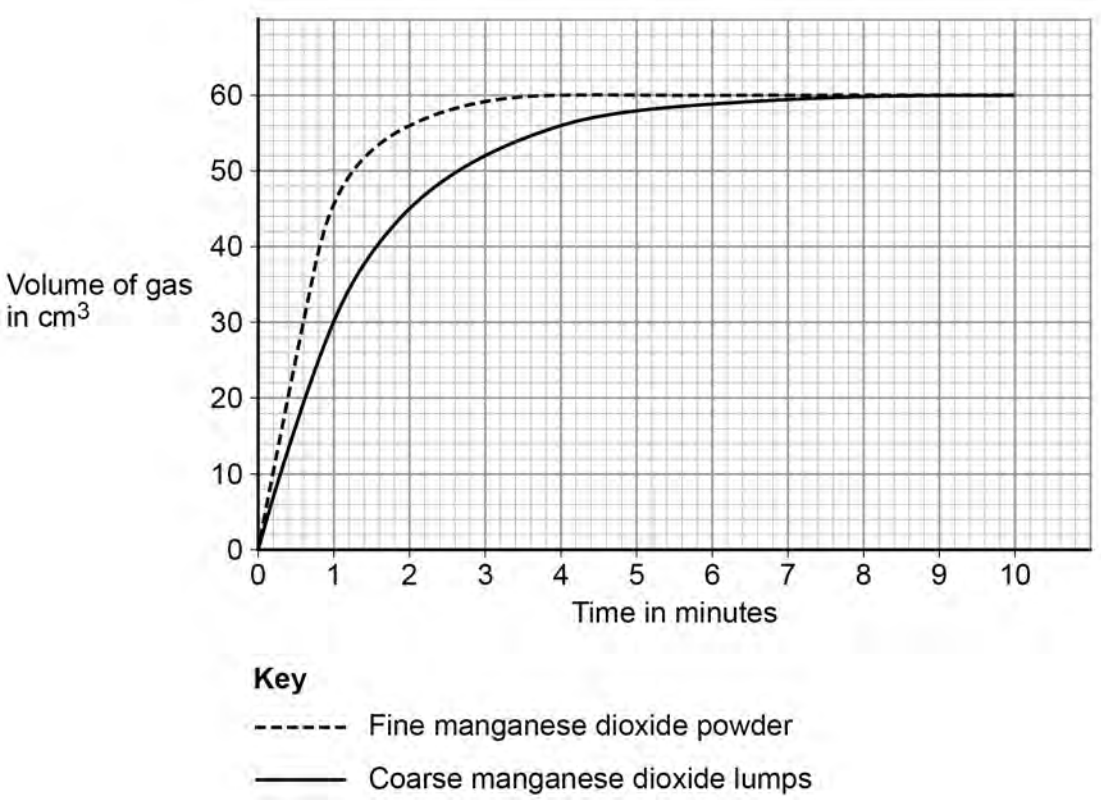
Question 9 continues on the next page

Question 40 · continued

Student **B** used a method which gave valid results.

Figure 9 shows student **B**'s results.

Figure 9



0 9 . 3 Determine the mean rate of reaction in cm^3/s between 2 and 4 minutes for coarse manganese dioxide lumps.

Give your answer to 2 significant figures.

Use data from **Figure 9**.

[3 marks]

Mean rate of reaction = _____ cm^3/s

4.6.1.4 Catalysts

Question 40 · continued

Hydrogen peroxide molecules must collide with manganese dioxide particles for catalysis to take place.

0 9 . 4 Student **B** repeated the experiment with coarse lumps of manganese dioxide.

Student **B** used the same volume of 0.2 mol/dm^3 hydrogen peroxide instead of 0.3 mol/dm^3 hydrogen peroxide.

Sketch on **Figure 9** the curve you would expect to see.

Assume that the reaction is complete after 9 minutes.

[2 marks]

0 9 . 5 The rate of reaction is different when manganese dioxide is used as a fine powder rather than coarse lumps.

Explain why.

You should answer in terms of collision theory.

[2 marks]

11

4.6.1.4 Catalysts

Question 41

June 2022 | 8462/2H | Original Q7

0 7 Ammonia is produced in the Haber process.

The raw materials for the Haber process are nitrogen and hydrogen.

The equation for the reaction is:

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

0 7 . 1 Give the sources of the nitrogen and of the hydrogen used in the Haber process.

[2 marks]

Nitrogen _____

Hydrogen _____

0 7 . 2 How does the equation for the reaction show that the atom economy of the forward reaction is 100%?

[1 mark]

_____

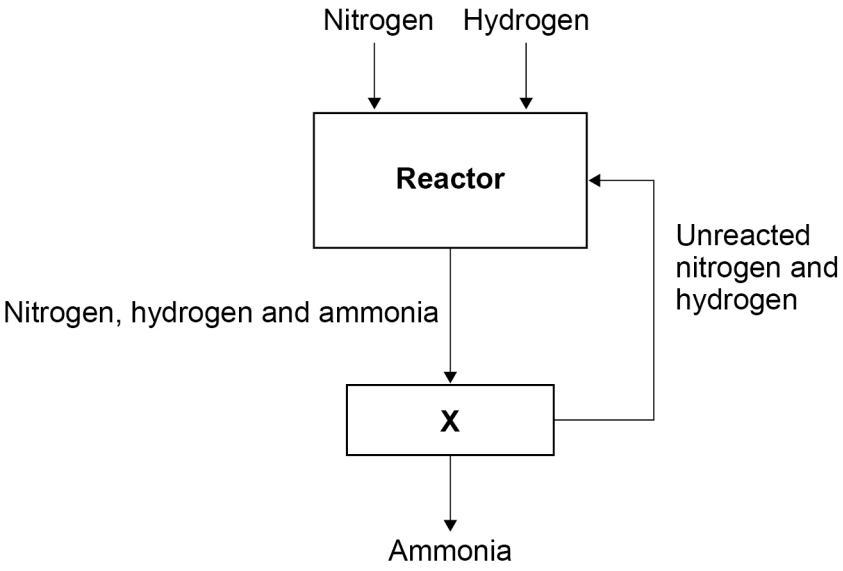
_____

4.6.1.4 Catalysts

Question 41 · continued

0 7 . 3 **Figure 4** represents the Haber process.

Figure 4



Explain how the ammonia produced is separated from the unreacted nitrogen and hydrogen in **X**.

[2 marks]

Question 7 continues on the next page

4.6.1.4 Catalysts

Question 41 · continued

The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

Table 6 shows the percentage yield of ammonia produced at 450 °C using different pressures.

Table 6

Pressure in atmospheres	Percentage (%) yield of ammonia
60	9
120	18
180	25
240	31
300	36
360	40
420	43

4.6.1.4 Catalysts

Question 41 · continued

0 7 . 4 Complete **Figure 5**.

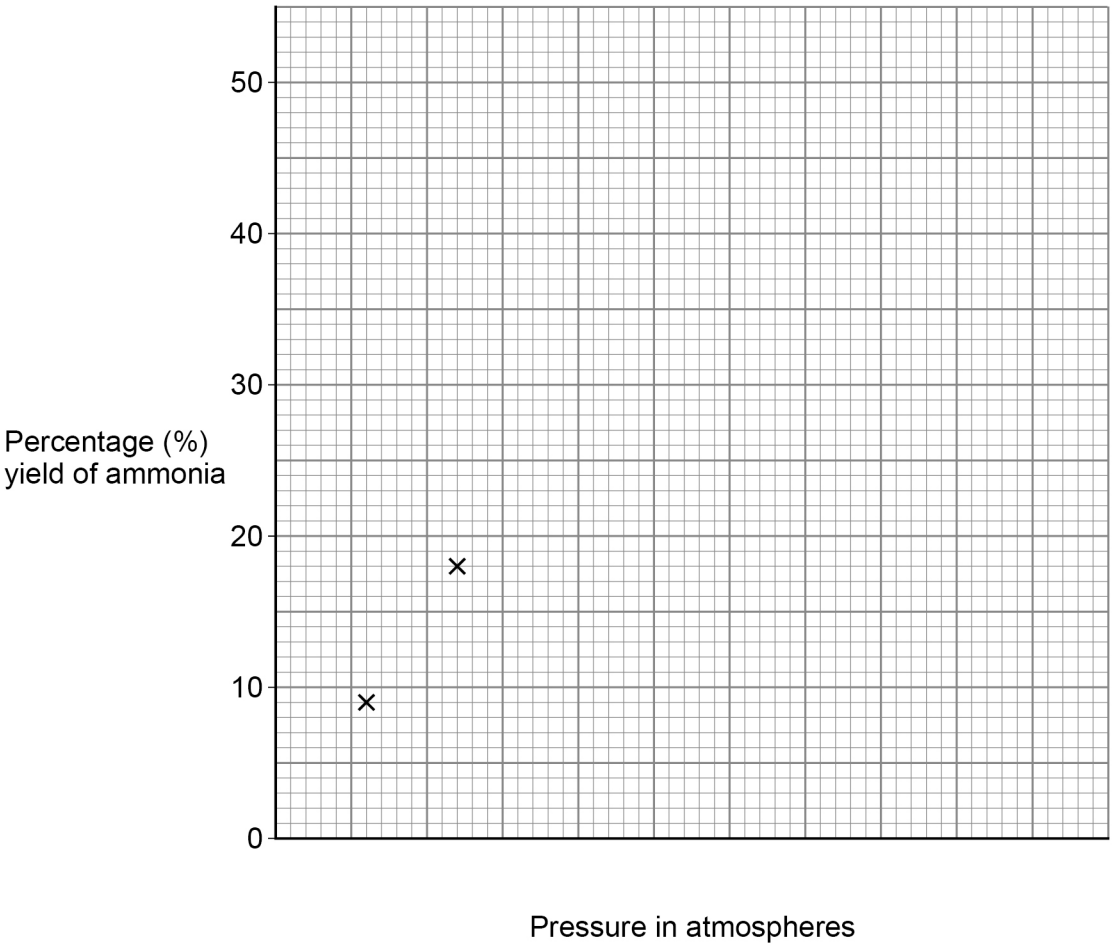
The first two points have been plotted.

You should:

- use a suitable scale for the *x*-axis
- plot the remaining data from **Table 6**
- draw a line of best fit.

[4 marks]

Figure 5



0 7 . 5 Determine the percentage yield of ammonia at 450 °C and 500 atmospheres.

Show your working on **Figure 5**.

[2 marks]

Percentage yield = _____ %

4.6.1.4 Catalysts

Question 41 · continued

0 7 . 6 The equation for the production of ammonia in the Haber process is:

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

The forward reaction is exothermic.

The conditions used are:

- a temperature of 450 °C
- a pressure of 200 atmospheres
- the presence of an iron catalyst.

Explain why these conditions are chosen for economical production of ammonia in the Haber process.

You should include references to the rate of reaction and the position of equilibrium.

[6 marks]

17

4.6.1.4 Catalysts

Question 42

June 2023 | 8462/2H | Original Q7

0 7 Manganese dioxide catalyses the decomposition of hydrogen peroxide solution.

Oxygen and water are produced.

0 7 . 1 Explain how a manganese dioxide catalyst increases the rate of decomposition of hydrogen peroxide.

[2 marks]

A student investigated the rate of this reaction.

This is the method used.

1. Add 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution to a conical flask.

2. Add 1.0 g of manganese dioxide to the conical flask.

3. Place the conical flask on a balance and start a timer.

4. Record the total mass lost from the conical flask every 20 seconds for 180 seconds.

0 7 . 2 Explain why the mass of the conical flask and contents decreased.

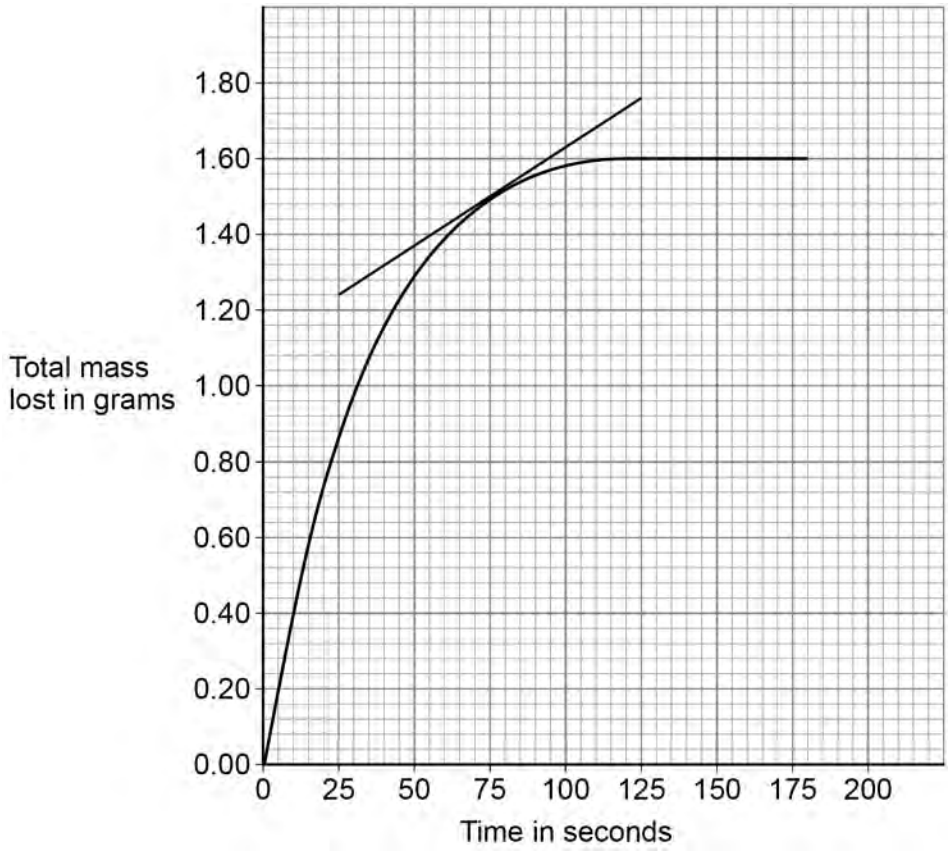
[2 marks]

Question 42 · continued

0 7 . 3 **Figure 4** shows the results for 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide.

A tangent to the line has been drawn at 75 seconds.

Figure 4



Determine the rate of reaction when the time was 75 seconds.

Give your answer to 2 significant figures.

[4 marks]

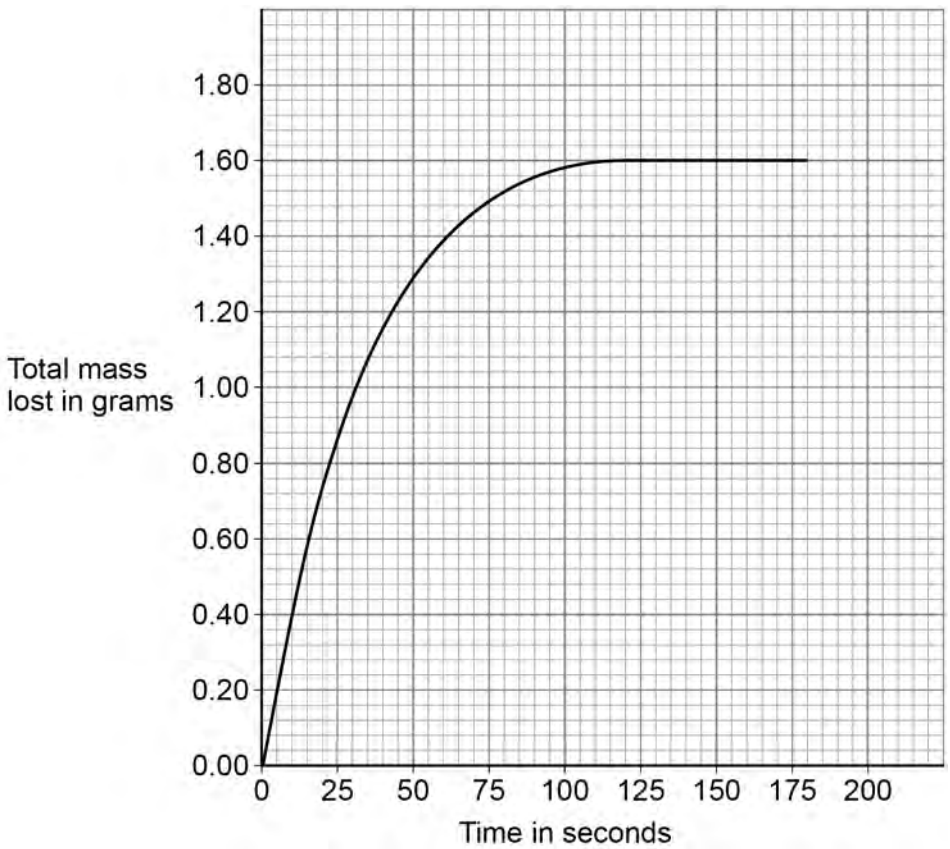
Rate (2 significant figures) = _____ g/s

4.6.1.4 Catalysts

Question 42 · continued

0 7 . 4 The results for 50 cm^3 of 2.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide are shown again on **Figure 5**.

Figure 5



The student repeated the investigation using 50 cm^3 of 1.0 mol/dm^3 hydrogen peroxide solution and 1.0 g of manganese dioxide.

Sketch the expected results for 1.0 mol/dm^3 hydrogen peroxide solution on **Figure 5**.

[2 marks]

10

4.6.1.4 Catalysts

Question 43

June 2023 | 8462/2H | Original Q9

0 9 This question is about reversible reactions.

When 4.68 g of hydrated copper sulfate changes into anhydrous copper sulfate:

- 2.99 g of anhydrous copper sulfate is produced
- 1.47 kJ of energy is taken in from the surroundings.

The equation for the reversible reaction is:

hydrated copper sulfate ⇌ anhydrous copper sulfate + water

0 9 . 1 Calculate the maximum mass of water that can be produced from 11.7 g of hydrated copper sulfate.

[3 marks]

Mass = _____ g

0 9 . 2 15.0 g of anhydrous copper sulfate completely changes into hydrated copper sulfate when water is added.

Calculate the amount of energy transferred to the surroundings.

[2 marks]

Energy = _____ kJ

4.6.1.4 Catalysts

Question 43 · continued

The gases nitrogen dioxide and dinitrogen tetroxide reach dynamic equilibrium in a sealed container.

The equation for the reaction is:

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

nitrogen dioxide (brown) — dinitrogen tetroxide (colourless)

The forward reaction is exothermic.

0 9 . 3 What happens to the position of the equilibrium in this reaction if the temperature is increased?

[1 mark]

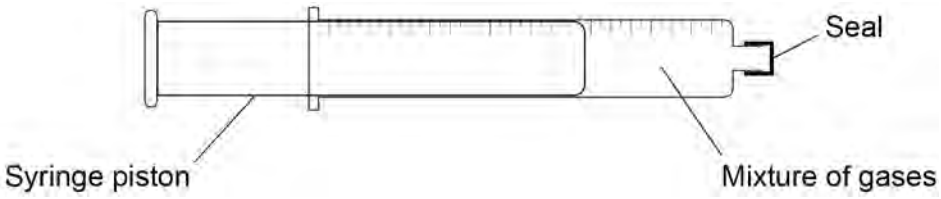
Tick (✓) **one** box.

- Shifts to the left ☐
- Stays the same ☐
- Shifts to the right ☐

0 9 . 4 A teacher seals a brown-coloured mixture of nitrogen dioxide and dinitrogen tetroxide in a gas syringe.

Figure 8 shows the sealed gas syringe.

Figure 8



The teacher pushes the syringe piston in.

This increases the pressure in the gas syringe.

What is the colour of the mixture when a new equilibrium position is reached?

[1 mark]

Tick (✓) **one** box.

The mixture is a darker shade of brown. ☐

The mixture is the same shade of brown. ☐

The mixture is a lighter shade of brown. ☐

Question 9 continues on the next page

4.6.1.4 Catalysts

Question 43 · continued June 2023 | 8462/2H | Original Q9

Hydrogen iodide gas decomposes into hydrogen gas and iodine gas at high temperatures.

The equation for the reaction is:

$$2\,HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

0 9 . 5 Explain the effect of increasing the pressure on the equilibrium position of this reaction.

[2 marks]

0 9 . 6 Suggest the effect of adding a catalyst on the equilibrium position of this reaction.

[1 mark]

4.6.1.4 Catalysts

Question 43 · continued

Copper forms coloured compounds.

Hydrochloric acid is added to an aqueous solution of copper compound **A**.

The word equation for the reaction is:

copper compound **A** (blue) + hydrochloric acid ⇌ copper compound **B** (yellow) + water

0 9 . 7 The reaction mixture is green when both copper compounds are present in a solution at equilibrium.

How can the equilibrium position be shifted to make the reaction mixture more yellow?

[1 mark]

Tick (✓) **one** box.

- Add more hydrochloric acid ☐
- Add more water ☐
- Leave the reaction mixture for 30 minutes ☐

0 9 . 8 The concentrations of the substances in this reaction do **not** change at dynamic equilibrium.

Explain why.

[2 marks]

13

4.6.1.4 Catalysts

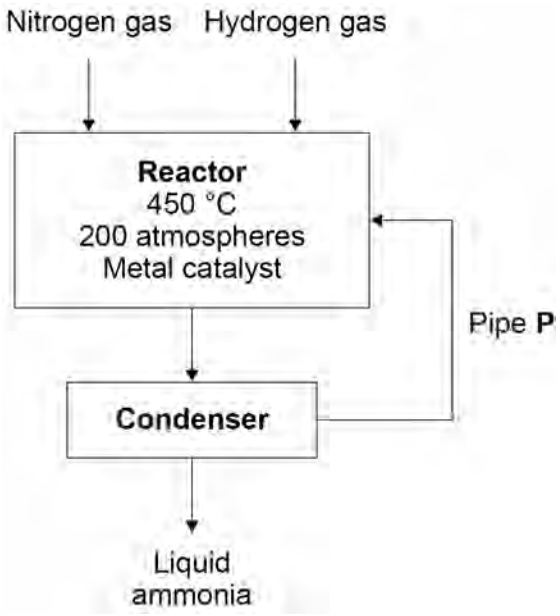
Question 44

0 2 This question is about ammonia and nitric acid.

In the Haber process ammonia is produced from nitrogen and hydrogen.

Figure 1 represents the Haber process.

Figure 1



0 2 . 1 Pipe **P** links the condenser to the reactor.

Why is the condenser linked to the reactor?

Use **Figure 1**.

[1 mark]

0 2 . 2 Which metal is used as a catalyst in this reaction?

[1 mark]

Question 44 · continued

Nitric acid is produced by reacting ammonia with oxygen.

The word equation for the production of nitric acid is:

ammonia + oxygen → water + nitric acid

Platinum is a catalyst in this reaction.

0 2 . 3 Describe the test for oxygen gas.

Give the result if oxygen gas is present.

[2 marks]

Test _____

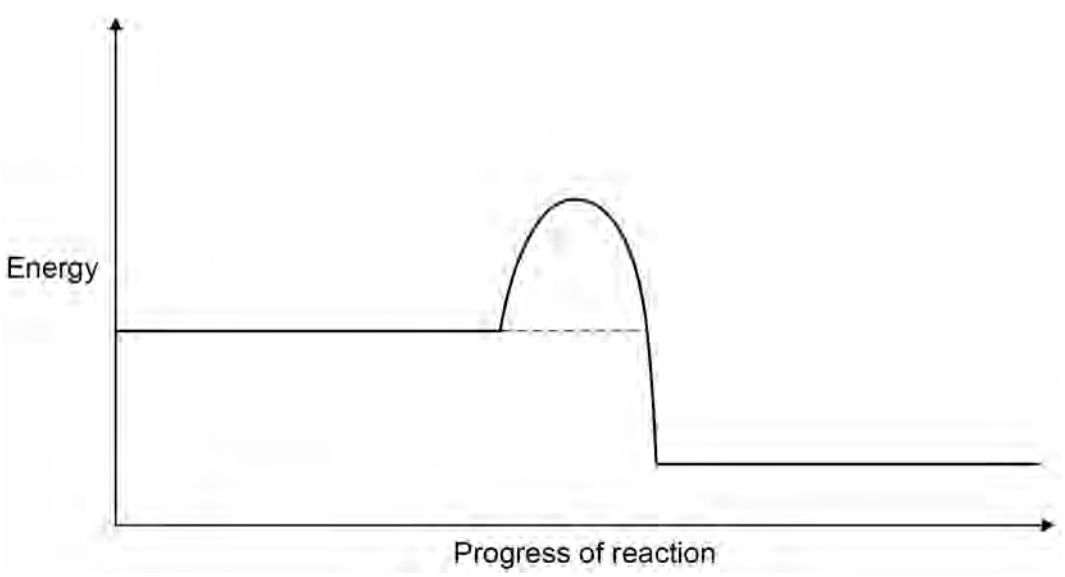
_____

Result _____

_____

Figure 2 represents the reaction profile of the catalysed reaction between ammonia and oxygen.

Figure 2



4.6.1.4 Catalysts

Question 44 · continued

0 2 . 4 Complete the reaction profile for the catalysed reaction in **Figure 2**.

You should:

- label the activation energy
- label the reactants and products, using the names of the reactants and products.

[2 marks]

0 2 . 5 How would **Figure 2** be different if **no** catalyst was used?

[1 mark]

Tick (✓) **one** box.

The final energy level would be higher. ☐

The final energy level would be lower. ☐

The line would reach a higher peak. ☐

The line would reach a lower peak. ☐

0 2 . 6 Ammonia and nitric acid react to produce the salt, ammonium nitrate.

Ammonium ions and nitrate ions both contain nitrogen.

Suggest **one** use of ammonium nitrate.

[1 mark]

_____

_____

8

4.6.1.4 Catalysts

Question 45

June 2024 | 8462/2H | Original Q7

0 7 This question is about sulfuric acid.

0 7 . 1 Sulfuric acid contains sulfate ions.

Describe the test for the presence of sulfate ions in sulfuric acid.

Give the result of the test.

[2 marks]

Test _____

_____

Result _____

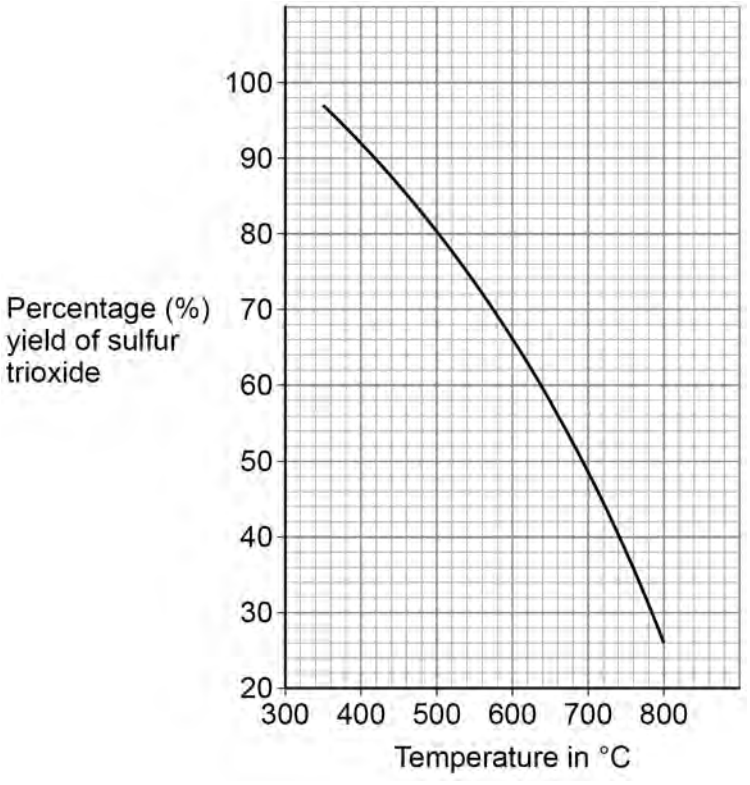
_____

One stage in the industrial production of sulfuric acid is the reaction of sulfur dioxide with oxygen to produce sulfur trioxide.

This reversible reaction reaches dynamic equilibrium.

Figure 7 shows the percentage yield of sulfur trioxide in this reaction at different temperatures.

Figure 7



Question 45 · continued

0 7 . 2 Which statement about the forward reaction is correct?

Use **Figure 7**.

[1 mark]

Tick (✓) **one** box.

- The yield is greater at higher temperatures because the reaction is exothermic. ☐
- The yield is greater at higher temperatures because the reaction is endothermic. ☐
- The yield is smaller at higher temperatures because the reaction is exothermic. ☐
- The yield is smaller at higher temperatures because the reaction is endothermic. ☐

The equation for the reaction is:

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

0 7 . 3 Explain why the percentage yield of sulfur trioxide in this reaction is greater if the pressure is higher.

[2 marks]

0 7 . 4 In industry, the reaction is done at 450 °C and atmospheric pressure.

Under these conditions the yield of sulfur trioxide is 86%.

Suggest **two** reasons why a higher pressure is **not** used.

[2 marks]

1

2

4.6.1.4 Catalysts

Question 45 · continued

0 7 . 5 This reaction uses a catalyst to increase the rate of the reaction.

The catalyst is a metal oxide.

Which is the most likely metal in the metal oxide catalyst?

Use the periodic table.

[1 mark]

Tick (✓) **one** box.

Aluminium (Al) ☐

Barium (Ba) ☐

Potassium (K) ☐

Vanadium (V) ☐

8

4.6.1.4 Catalysts

Question 46

June 2025 | 8462/1H | Original Q7

0 7 Hydrazine (N_2H_4) is a compound of nitrogen and hydrogen.

0 7 . 1 Scientists are researching the use of hydrazine in fuel cells.

Table 2 gives some information about the use of hydrogen and hydrazine in fuel cells.

Table 2

	Hydrogen	**Hydrazine**
State at room temperature	Gas	Liquid
Hazards	Explosive	Toxic
Equation for fuel cell reaction	$2\ H_2\ +\ O_2\ \longrightarrow\ 2\ H_2O$	$N_2H_4\ +\ O_2\ \longrightarrow\ N_2\ +\ 2\ H_2O$
Voltage produced in volts	1.23	1.61
Catalyst needed for reaction	Platinum	None

Evaluate the use of hydrazine instead of hydrogen in a fuel cell.

[4 marks]

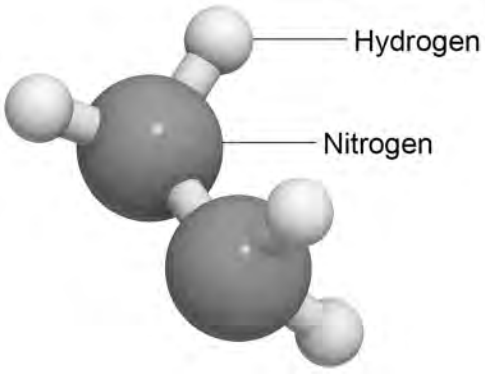
Extra space

4.6.1.4 Catalysts

Question 46 · continued

Figure 6 shows a model of the hydrazine molecule.

Figure 6

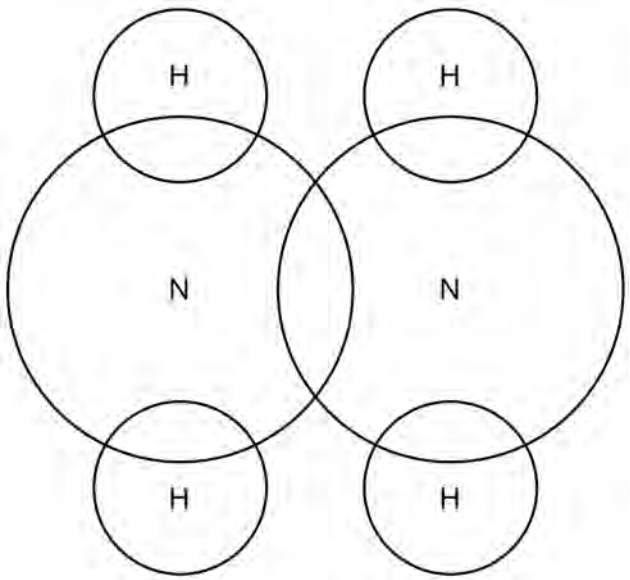


0 7 . 2 Complete the dot and cross diagram for hydrazine in **Figure 7**.

Show the outer shell electrons only.

[2 marks]

Figure 7



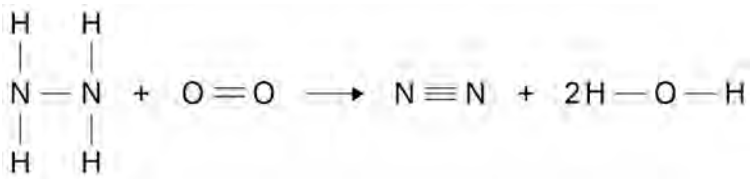
0 7 . 3 Give **one** advantage of the ball and stick model in **Figure 6** compared to the dot and cross diagram.

[1 mark]

Question 46 · continued

0 7 . 4 **Figure 8** shows the displayed formula equation for the reaction of hydrazine with oxygen.

Figure 8



The reaction is exothermic.

The energy released forming new bonds is 581 kJ/mol greater than the energy needed to break existing bonds.

Table 3 shows some bond energies.

Table 3

Bond	N — N	N — H	O = O	N ≡ N	O — H
Bond energy in kJ/mol	X	391	498	945	464

Calculate the bond energy (**X**) of the N — N bond.

[4 marks]

X = _____ kJ/mol

11

4.6.1.4 Catalysts

Question 47

June 2025 | 8462/2H | Original Q8

0 8 Hydrogen peroxide decomposes into water and oxygen.

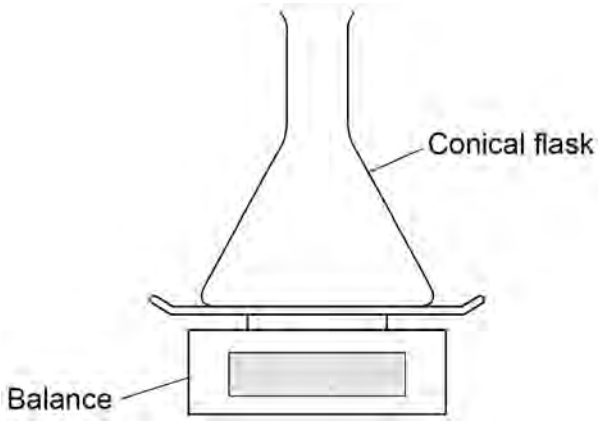
The equation for the reaction is:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

A student investigated the effect of catalyst **A** and of catalyst **B** on the rate of this reaction.

Figure 6 shows the apparatus.

Figure 6



This is the method used.

1. Put the conical flask on the balance.
2. Add 50 cm^3 of 1.5 mol/dm^3 hydrogen peroxide solution to the conical flask.
3. Add 1.00 g of catalyst **A** to the conical flask.
4. Start a timer.
5. Record the loss in mass of the conical flask and contents every 30 seconds for 3 minutes.
6. Repeat steps 1 to 5 using catalyst **B**.

0 8 . 1 Explain why the conical flask and contents lost mass.

[2 marks]

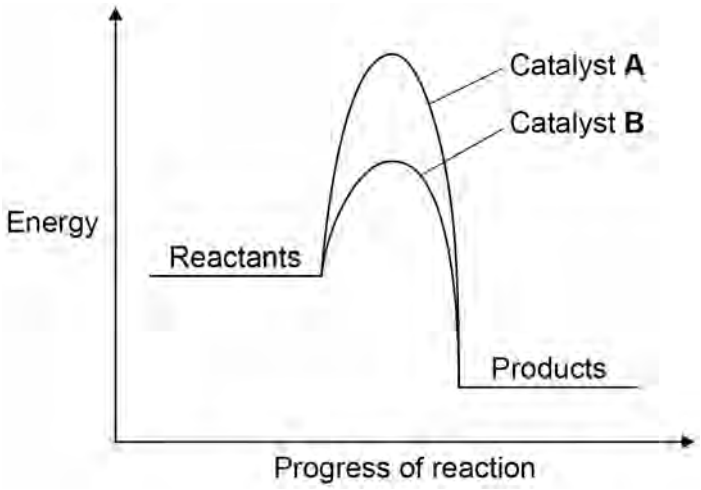
4.6.1.4 Catalysts

Question 47 · continued

0 8 . 2 **Figure 7** shows the reaction profile for the decomposition of hydrogen peroxide using:

- catalyst **A**
- catalyst **B**.

Figure 7



Explain why catalyst **A** and catalyst **B** give different rates of reaction for the decomposition of hydrogen peroxide.

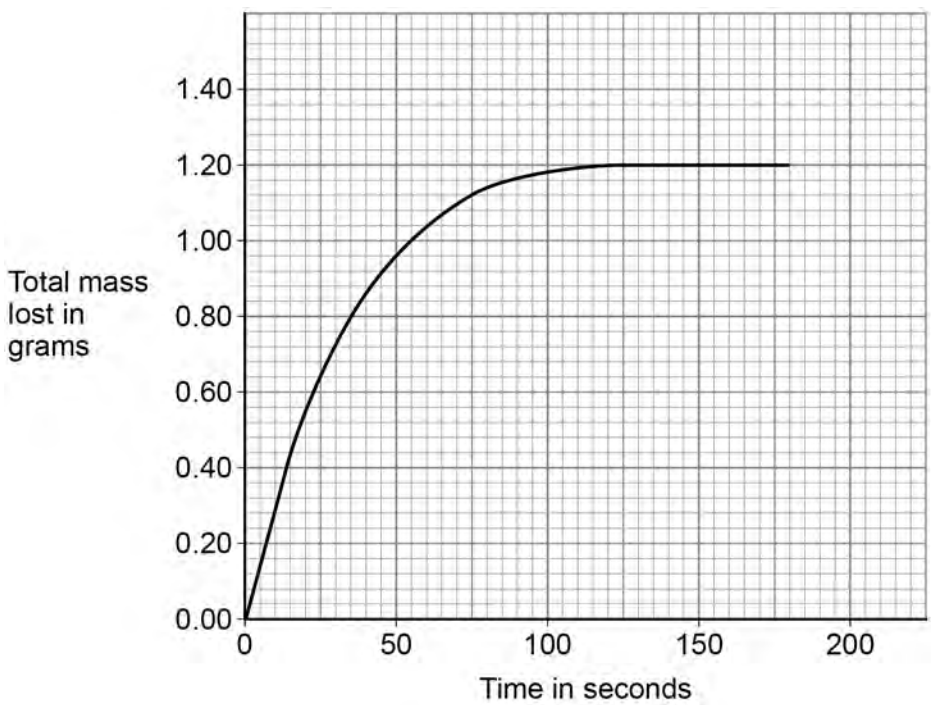
[3 marks]

Question 8 continues on the next page

Question 47 · continued

0 8 . 3 **Figure 8** shows the results for catalyst **A**.

Figure 8



Determine the rate of the reaction when the time was 60 seconds.

Give your answer in standard form.

[5 marks]

Rate (standard form) = _____ g/s

4.6.1.4 Catalysts

Question 47 · continued

0 8 . 4 Explain how the rate of decomposition of hydrogen peroxide depends on the temperature of the solution.

[3 marks]

13

Turn over for the next question

4.6.1.4 Catalysts

Question 48

June 2025 | 8462/2H | Original Q9

0 9 This question is about ammonia.

Ammonia is produced from nitrogen and hydrogen in the Haber process.

Hydrogen is produced from methane and steam.

The equation for one of the reactions in the production of hydrogen is:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3\,H_2(g)$$

The forward reaction absorbs energy from the surroundings.

0 9 . 1 Explain why a high temperature is used in this reaction.

[3 marks]

0 9 . 2 Explain why as low a pressure as possible is used in this reaction.

[2 marks]

4.6.1.4 Catalysts

Question 48 · continued

0 9 . 3 A nickel catalyst is used in this reaction.

What is the effect of the nickel catalyst on the position of equilibrium?

[1 mark]

Tick (✓) **one** box.

Equilibrium position shifts to the left. ☐

No effect on equilibrium position. ☐

Equilibrium position shifts to the right. ☐

0 9 . 4 The nitrogen needed in the Haber process is obtained from air.

Calculate the approximate volume of air required to obtain 50 dm^3 of nitrogen.

[2 marks]

Volume ~ _____ dm^3

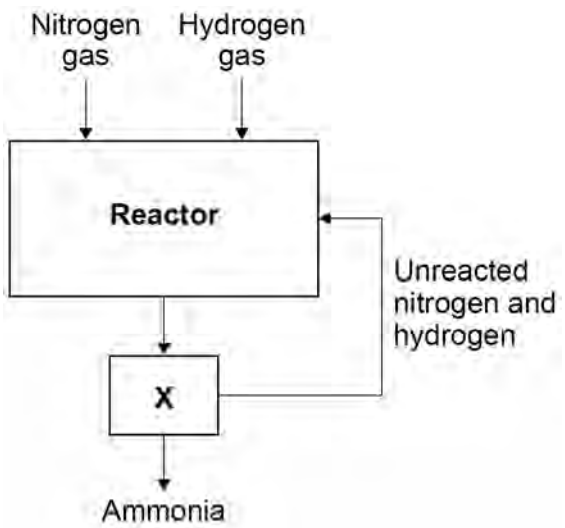
Question 9 continues on the next page

4.6.1.4 Catalysts

Question 48 · continued

0 9 . 5 **Figure 9** shows how ammonia is produced from nitrogen and hydrogen.

Figure 9



Explain how the mixture of ammonia, nitrogen and hydrogen is separated at **X**.

[3 marks]

4.6.1.4 Catalysts

Question 48 · continued

0 9 . 6 Ammonia is used to produce fertilisers.

Nitrogen is released into the air when bacteria break down fertilisers and dead plant matter.

One of the reactions during the production of hydrogen from methane (natural gas) releases carbon dioxide into the air.

The use of nitrogen to produce ammonia is more sustainable than the use of hydrogen to produce ammonia.

Give **three** reasons why.

[3 marks]

1 _____

_____

2 _____

_____

3 _____

_____

14