PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: KINETICS

SCORE	PERCENTAGE
/189	%

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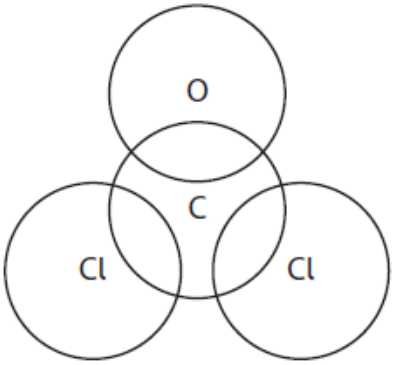
Q1.

Phosgene ($COCl_2$) is a colourless gas used in the pharmaceutical industry.

Phosgene has a boiling temperature of 8 °C and is extremely toxic.

(a) Complete the dot-and-cross diagram to show the bonding in phosgene.

(2)



(b) Phosgene can be formed from carbon monoxide and chlorine, using a catalyst of activated carbon.

$$CO(g) + Cl_2(g) \leftrightarrow COCl_2(g) \qquad \Delta_r H = -107.6 \text{ kJ mol}^{-1}$$

(i) State and explain how the reaction conditions could be changed to maximise the **equilibrium** yield of phosgene in this reaction.

(4)

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(ii) The standard enthalpy change of formation for phosgene is $\Delta_f H = -220.1$ kJ mol^{-1}.

Complete the Hess cycle and determine the standard enthalpy change of formation for carbon

monoxide. Use the data from (b)(i).

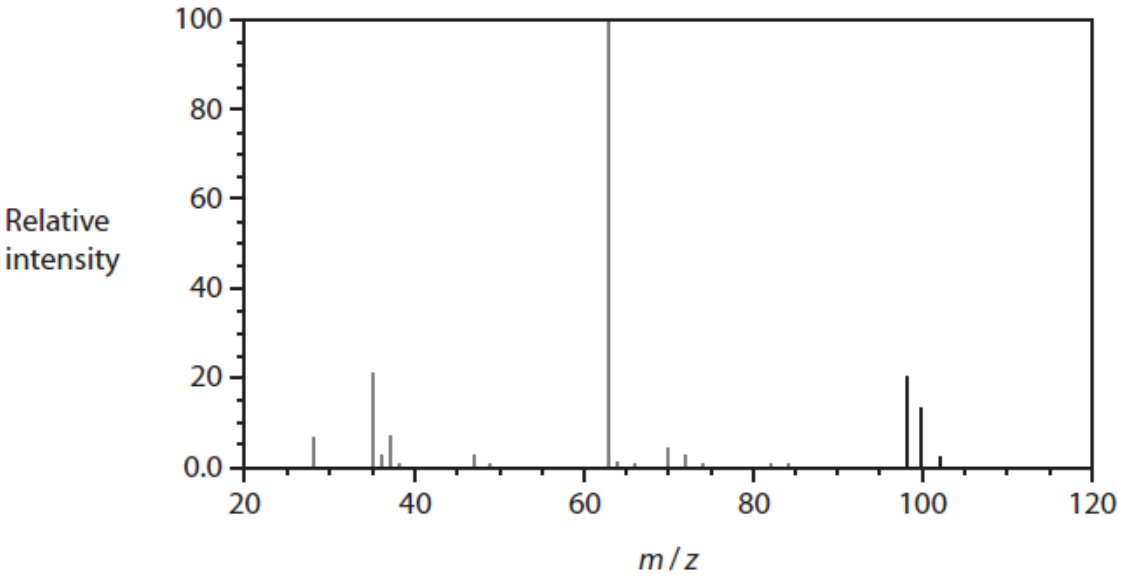
Include state symbols in your cycle.

(4)

$CO(g) \quad + \quad Cl_2(g) \quad \rightarrow \quad COCl_2(g)$

(c) The mass spectrum of a sample of phosgene is shown.

The peak at $m / z = 65$ has been omitted.



(i) Give the reason for the **ratio** of peak heights at m / z values of 102, 100 and 98.

(2)

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(ii) Suggest an identity for the peak at $m / z = 63$.

(1)

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(iii) The peak at $m / z = 65$ has been omitted.

Draw **on the mass spectrum** the peak at $m / z = 65$, showing its relative intensity.

(1)

(d) Use your Data Booklet to suggest the wavenumber of a strong absorbance you would expect to see in the infrared
spectrum for phosgene. Justify your answer.

(2)

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(e) In UV light, trichloromethane ($CHCl_3$, boiling temperature 61°C) reacts with oxygen to form phosgene and
hydrogen chloride.

(i) Write an equation for this reaction.
State symbols are not required.

(1)

(ii) In a closed bottle, the rate of this reaction decreases with time.

Give a reason for this.

(1)

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(iii) Suggest a precaution that should be taken when opening a bottle of trichloromethane.

(1)

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(iv) Trichloromethane can be used as an anaesthetic.

Suggest whether an old bottle of trichloromethane can still be used for medical treatment, giving a reason for your answer.

(1)

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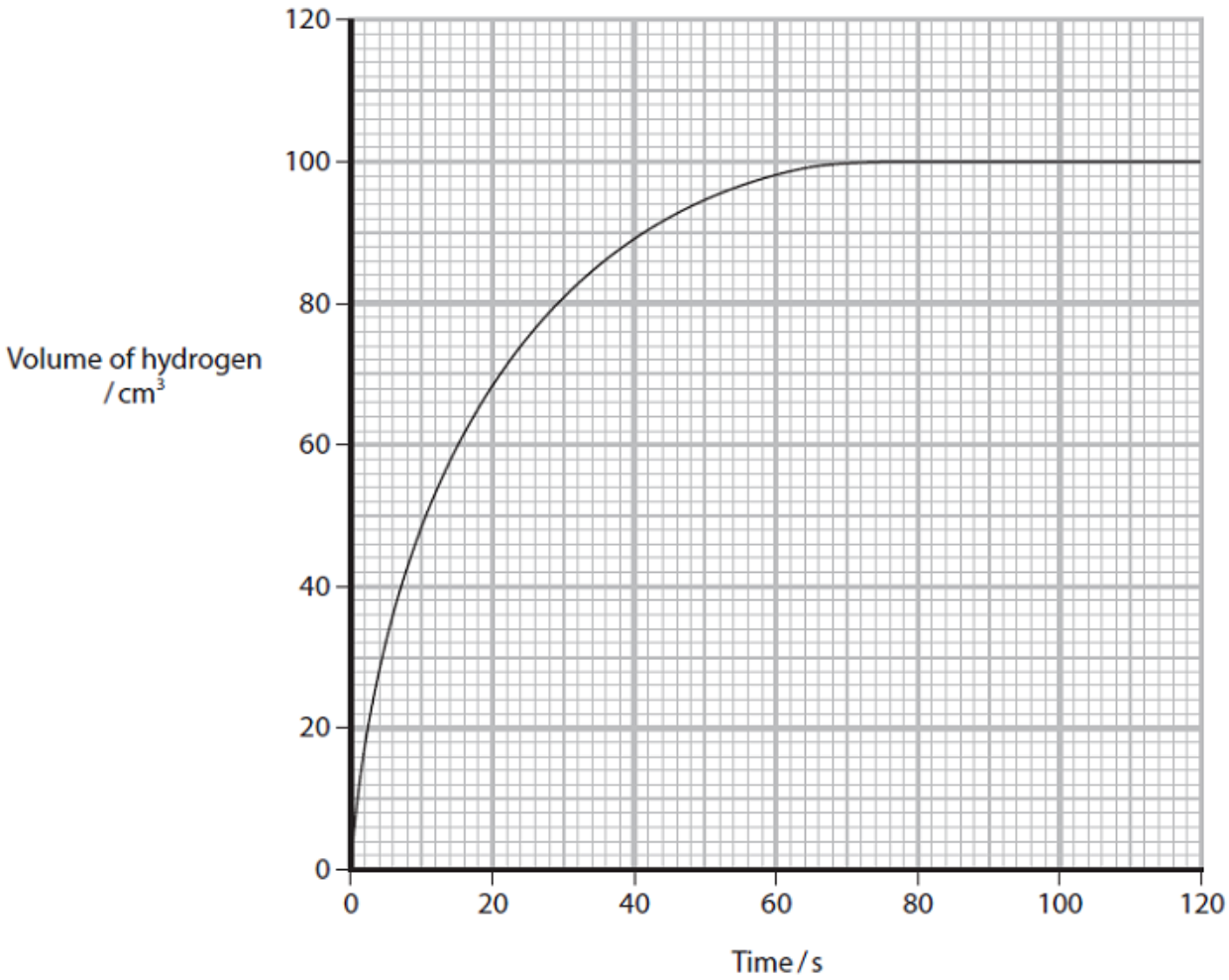
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(Total for question = 20 marks)

Q2.

The results of an experiment to determine the rate of the reaction between magnesium and hydrochloric acid are shown.



What is the **approximate** rate of reaction in $cm^3\ s^{-1}$ at 40 seconds?

☒ **A** 0.75

☒ **B** 1.3

☒ **C** 2.2

☒ **D** 6.0

(Total for question = 1 mark)

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Q3.

This question is about calcium carbonate, $CaCO_3$.

(a) Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Explain why calcium carbonate decomposes at a higher temperature than magnesium carbonate, in terms of the charge and size of the cations.

(3)

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(b) Calcium carbonate reacts with dilute hydrochloric acid.

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

A student determines the initial rate of this reaction by collecting the carbon dioxide in a gas syringe and measuring the volume at regular time intervals.

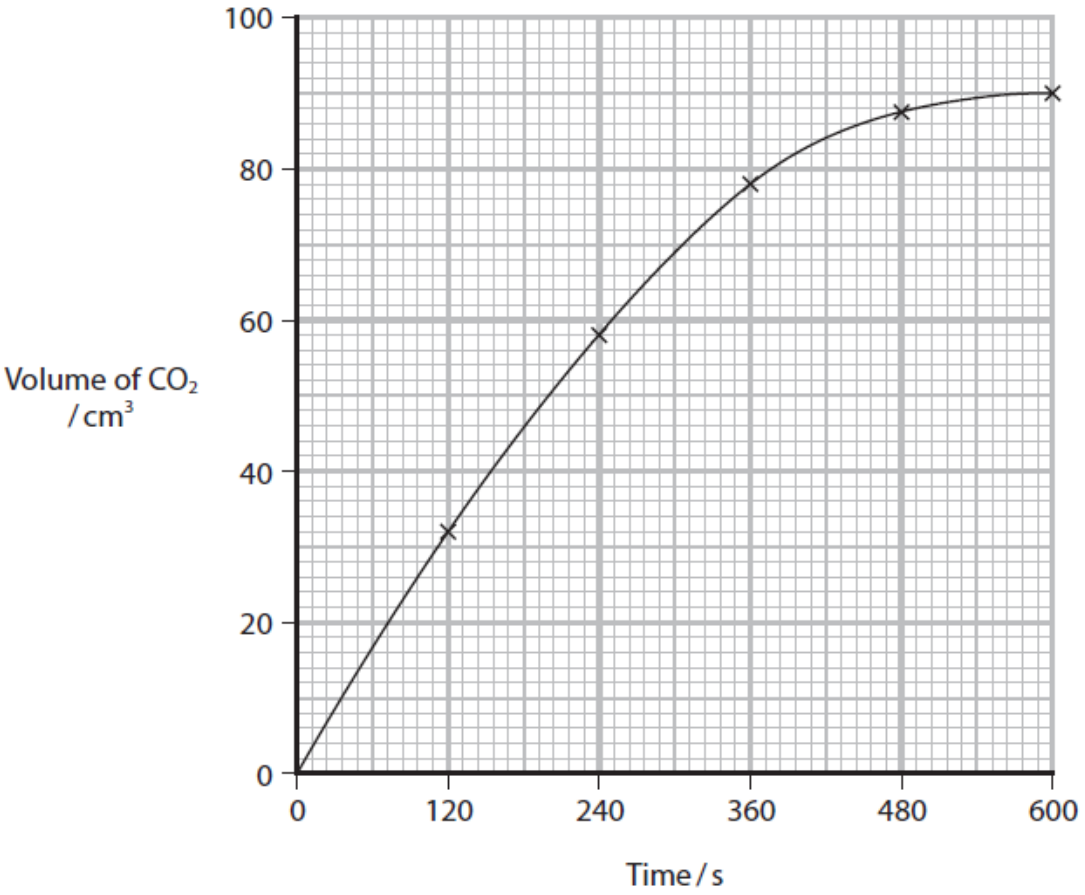
(i) The gas syringe can measure a maximum of 100 cm^3 of gas.

Calculate the **maximum** volume of 0.500 mol dm^{-3} hydrochloric acid that can be added to excess calcium carbonate at room temperature and pressure (r.t.p.) without exceeding the measurable volume of the gas syringe.

[Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(3)

(ii) The results of the student's experiment are shown on the graph.



Calculate the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

(3)

(iii) The student repeats the experiment but uses hydrochloric acid with a concentration of 0.250 mol dm^{-3}. All other variables are kept the same.

State what would happen to the initial rate of reaction and the final volume of carbon dioxide collected.

(1)

Initial rate of reaction

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Final volume of carbon dioxide collected

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(Total for question = 10 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The rate of a reaction doubles for each 10 K increase in temperature.
If the temperature of this reaction is increased from 298 K to 358 K the rate of the reaction increases by a factor of

☐ **A** 6

☐ **B** 12

☐ **C** 36

☐ **D** 64

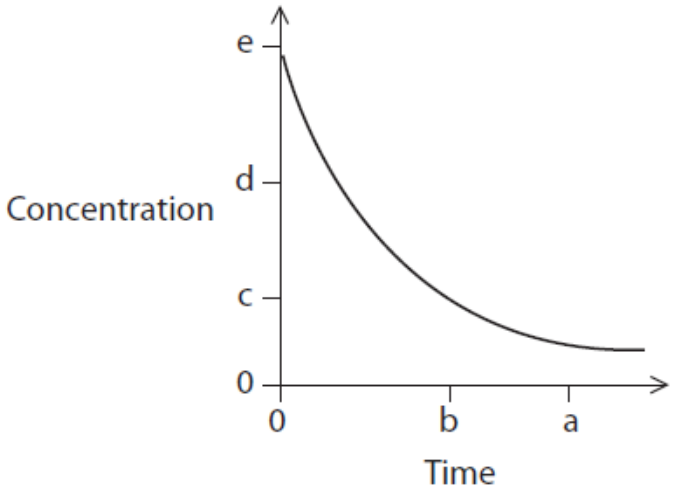
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(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows how the concentration of a reactant changes with time.



Which expression gives the best estimate for the value of the rate of this reaction at time b?

☒ **A** b ÷ c

☒ **B** d ÷ a

☒ **C** e ÷ a

☒ **D** e ÷ b

(Total for question = 1 mark)

Q6.

(a) The concentration of atmospheric carbon dioxide is at its highest level for 800 000 years.

Carbon Capture and Utilisation (CCU) uses waste carbon dioxide from industrial processes to make green fuels,
methanol, plastics or pharmaceuticals. One method uses the reaction between carbon dioxide and hydrogen to make methanol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta_r H = -49.5\,kJ\,mol^{-1}$$

The conditions for this industrial reaction are a pressure of 50 atm, a temperature of 250 °C and a copper catalyst.

(i) Explain why high pressure is used.

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(ii) Discuss the factors leading to a choice of 250 °C in this process.

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(iii) Give a reason why using a catalyst to increase the rate makes the process more sustainable.

(1)

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(b) Methanol can be oxidised to produce methanoic acid.

(i) State the reagents and reaction conditions for this oxidation in the laboratory.

(2)

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(ii) Complete the equation to show the products of this oxidation.

State symbols are not required.

(1)

$$CH_3OH + \text{.....} [O] \rightarrow$$

(iii) Give a chemical test, and its positive result, that could be used to confirm the functional group in methanoic acid.

(2)

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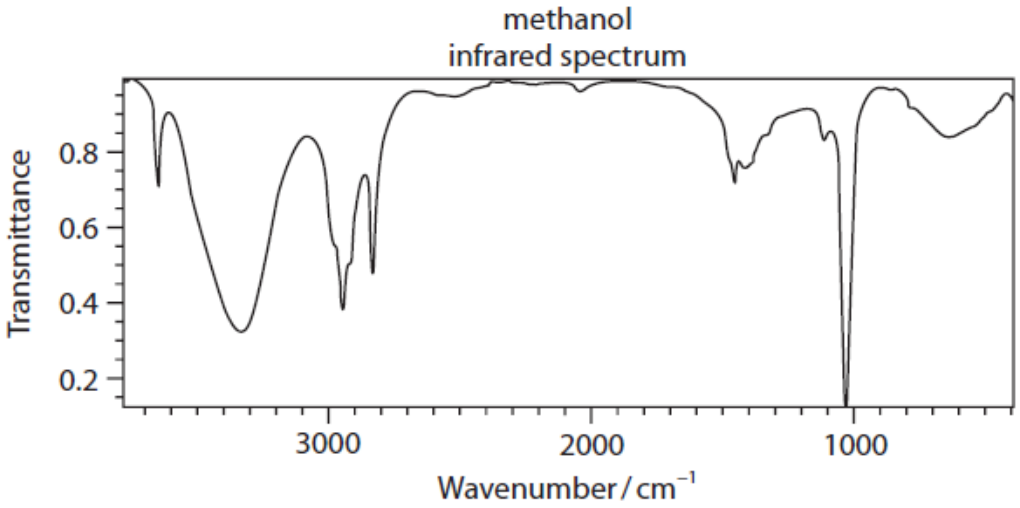
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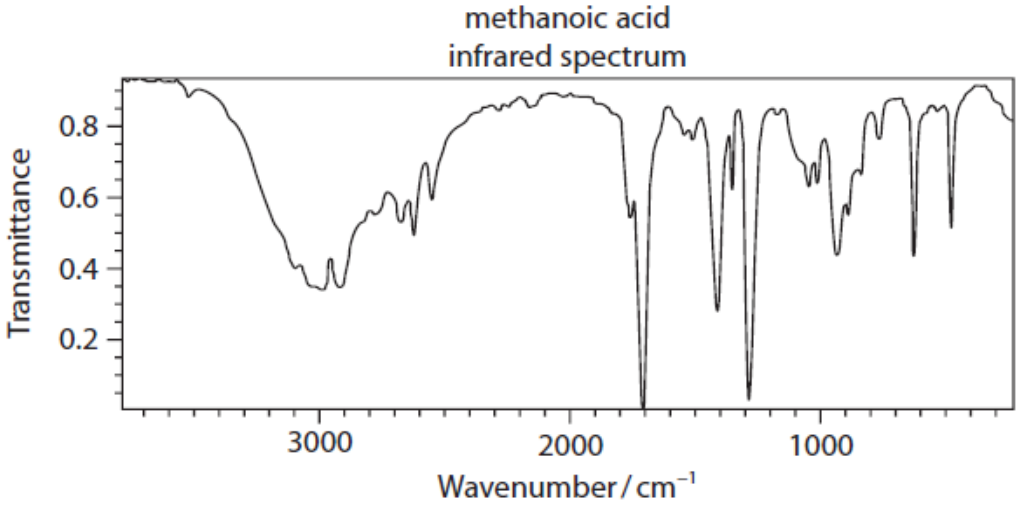
(iv) The infrared spectra of methanol and methanoic acid are shown.

Explain how these could be used to show that **all** the methanol has been converted to methanoic acid,
quoting relevant bonds and wavenumbers.

Use your Data Booklet.

(3)





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(c) (i) Methanol produced from petrol by CCU may be mixed with petrol derived from fossil fuels.

A concentration of 5% by mass of methanol is used.

Explain how the use of this fuel would affect the increase in global temperatures.

(2)

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(ii) Calculate the mass of carbon dioxide released when 1 mol of octane (C_8H_{18}) is burned completely.

(1)

(iii) A motorist who uses 1200 kg of fuel each year in a car changes to a fuel with 5% of the mass of petrol replaced
by methanol produced by CCU.

Calculate the annual reduction, in kg, of carbon dioxide released by the car.

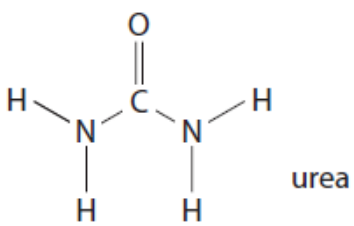
[Assume petrol has the same molecular formula as octane and the added methanol does not contribute any additional
carbon dioxide when burned.]

(2)

(Total for question = 19 marks)

Q7.

Some diesel cars contain an extra catalytic converter for the reduction of nitrogen oxides (NO_x) in exhaust gases.
A solution of urea is used for this process.



urea

(a) Urea has a melting temperature of 133 °C.

Explain why this value is higher than expected for a relatively small molecule.

(3)

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(b) A saturated solution of urea has a concentration of 9.07 mol dm^{-3} at 25°C.

Calculate the mass of urea in 150 cm^3 of a saturated solution.

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(c) State why NO_x emissions are harmful to the environment.

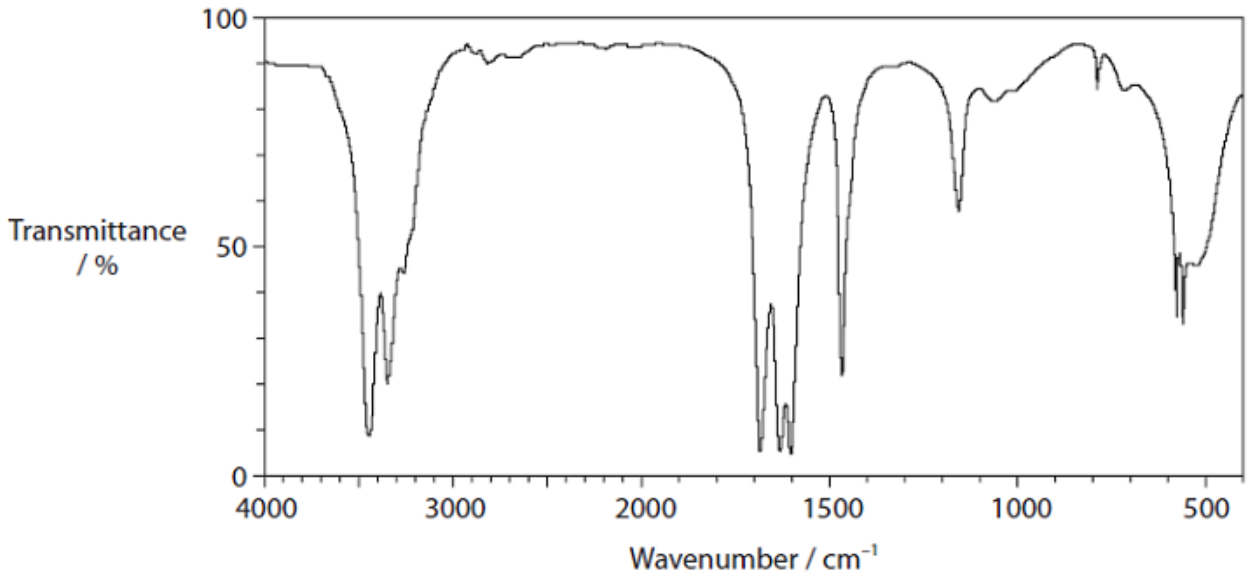
(1)

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(d) An infrared spectrum of urea is shown.

Refer to your Data Booklet.



(i) Draw a circle around an absorption in the spectrum that could be due to the stretching of the N—H bond.

(1)

(ii) Identify the bond responsible for the absorption at 1683 cm^{-1}.

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(1)

(e) In a diesel car exhaust system, the urea reacts with water to form ammonia and carbon dioxide. The enthalpy change for this reaction is +133 kJ mol^{-1}.

(i) Complete the equation for this **reversible** reaction.

State symbols are not required.

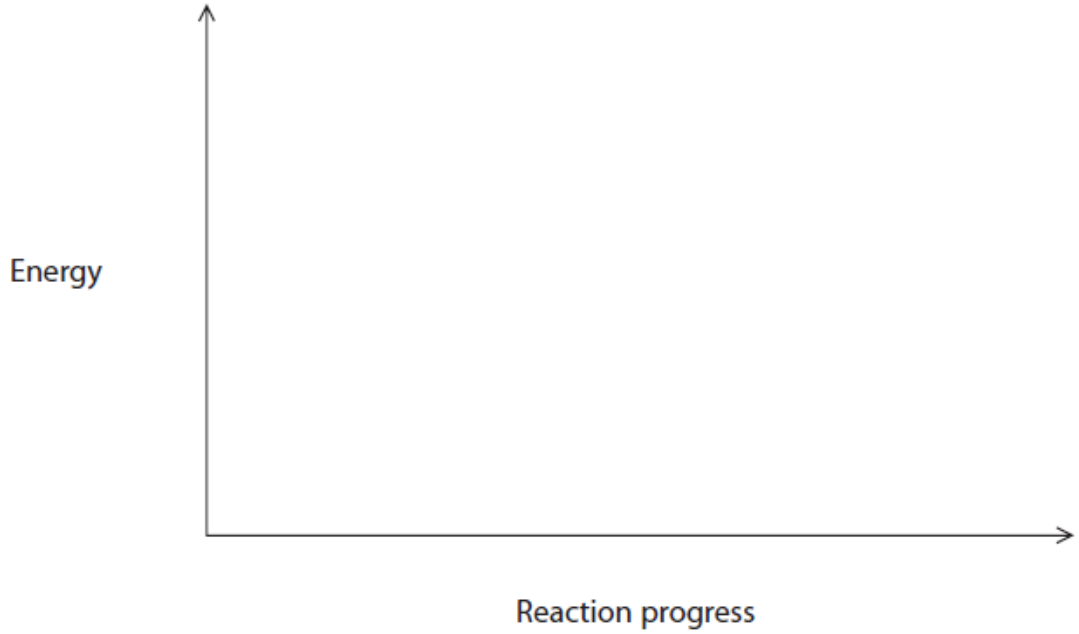
(1)

$(NH_2)_2CO + H_2O$

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(ii) Sketch the reaction profile for the forward reaction on the axes provided.

Include labels for ΔH and the activation energy (E_a).



(3)

(f) The catalytic converter contains metal oxides. When the exhaust gases pass through the catalytic converter, ammonia reacts with NO_x gases to form nitrogen and water.

(i) Explain why it is **not** correct to state that urea is acting as a catalyst in the reaction.

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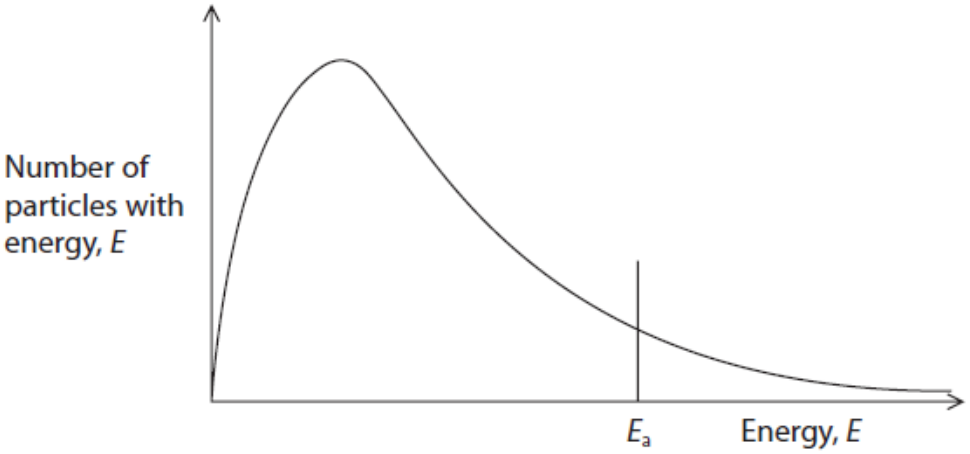
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(1)

(ii) Explain how a catalyst increases the rate of a chemical reaction.

Use the Maxwell-Boltzmann distribution shown and refer to the collision theory.

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(g) The catalytic converter works best at a temperature of around 350 °C.

(i) Suggest how the catalytic converter reaches this temperature.

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(ii) The chemical reactions in the exhaust system of a diesel car, using a catalytic converter, form 89.3 m^3 of nitrogen per hour.

Calculate the number of molecules of nitrogen formed per hour.

[Molar volume at 350 °C = 51.1 dm^3 mol^{-1}

Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}]

(3)

(Total for question = 20 marks)

Q8.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Hydrogen peroxide decomposes in the presence of a catalyst.

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

(a) What type of reaction occurs?

(1)

☒ **A** displacement

☒ **B** disproportionation

☒ **C** elimination

☒ **D** hydrolysis

(b) In an experiment, the volume of oxygen produced by the decomposition of hydrogen peroxide was measured at various times as the reaction progressed and a graph was plotted.

The initial gradient of the graph was 0.50 $cm^3\ s^{-1}$.

What is the initial rate of decomposition of hydrogen peroxide in mol s^{-1}?

[Molar volume of a gas at r.t.p. = 24 $dm^3\ mol^{-1}$]

(1)

☒ **A** 2.1×10^{-2} mol s^{-1}

☒ **B** 4.2×10^{-5} mol s^{-1}

☒ **C** 2.1×10^{-5} mol s^{-1}

☒ **D** 1.0×10^{-5} mol s^{-1}

(Total for question = 2 marks)

Q9.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Hydrogen peroxide decomposes as shown.

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

(a) A catalyst increases the rate of decomposition by

(1)

☐ **A** increasing the average kinetic energy of the H_2O_2 molecules

☐ **B** decreasing the average kinetic energy of the H_2O_2 molecules

☐ **C** increasing the activation energy of the reaction

☐ **D** decreasing the activation energy of the reaction

(b) A bottle of hydrogen peroxide is labelled as '10 volume'.

This means that 1 cm^3 of hydrogen peroxide solution decomposes to produce 10 cm^3 oxygen at room temperature and pressure (r.t.p.).

What is the concentration of 10 volume hydrogen peroxide, in mol dm^{-3}?

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

[Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(1)

☐ **A** 0.100

☐ **B** 0.208

☐ **C** 0.417

☐ **D** 0.833

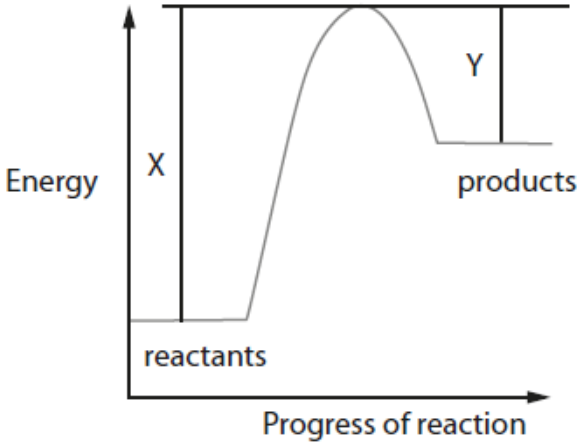
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(Total for question = 2 marks)

Q10.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The energy profile for a reaction is shown.



What is the minimum energy needed for this reaction to occur?

☒ **A** X

☒ **B** Y

☒ **C** X − Y

☒ **D** X + Y

(Total for question = 1 mark)

Q11.

This question is about ethanol and bioethanol.

The main fuel used as a petrol substitute is bioethanol. Bioethanol is ethanol that has been produced by fermentation. The starting material is usually some form of plant material rich in starch, such as wheat, maize or potatoes. Enzymes in yeast convert this material to simple carbohydrates such as glucose ($C_6H_{12}O_6$) and then to ethanol and carbon dioxide.

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

The mixture is left for several days until fermentation is complete.
The percentage of ethanol is never greater than 15 % because higher concentrations of ethanol kill the yeast.

A common blend of fuel is 95 % petrol and 5 % bioethanol. The engine does not need to be modified for this mixture.

(a) Give **one** advantage and **one** disadvantage of using bioethanol in petrol.

(2)

Advantage

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Disadvantage

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(b) Suggest why this fermentation must be carried out in the absence of air.

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(c) Suggest how the ethanol can be obtained, after filtering the fermentation mixture.

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(d) Ethanol is hygroscopic, which means it readily absorbs water from the air.

(i) Give a possible reason why ethanol is able to absorb water.

(1)

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(ii) Suggest a problem arising from the hygroscopic nature of ethanol when using this fuel in a motor vehicle.

(1)

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(e) Ethanol can also be produced by the hydration of ethene.

$$CH_2 = CH_2(g) + H_2O(g) \leftrightarrow CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

*(i) Typical conditions are 300 °C and 60 atm with a catalyst of phosphoric acid.

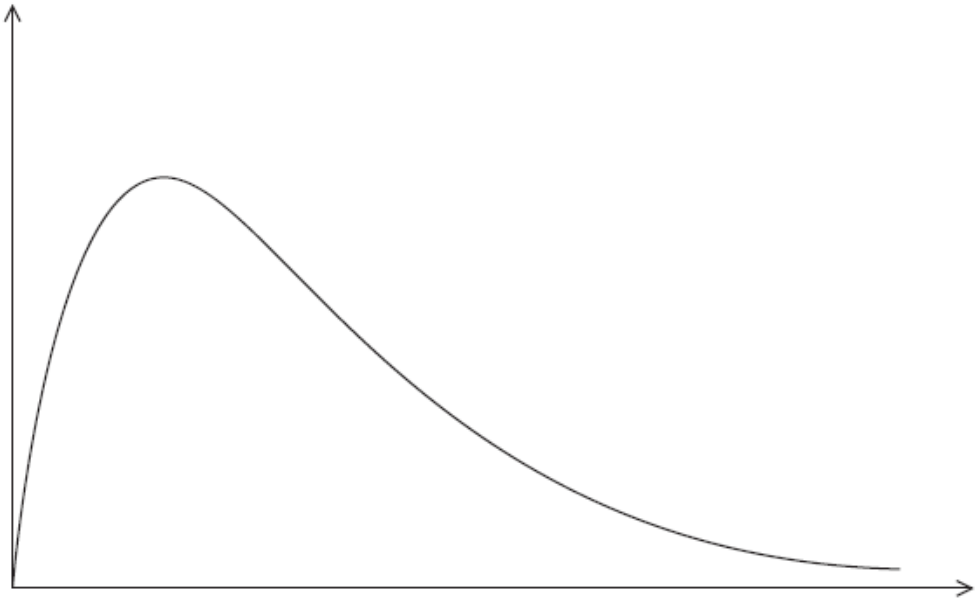
Explain why these conditions are used, by describing the effect of changing the temperature and pressure on rate of reaction, equilibrium yield and cost.

(6)

(ii) The rate of this reaction is increased by using a catalyst of phosphoric acid.

Label the axes on the Maxwell–Boltzmann distribution curve and use it to explain how a catalyst increases the rate of reaction.

(4)



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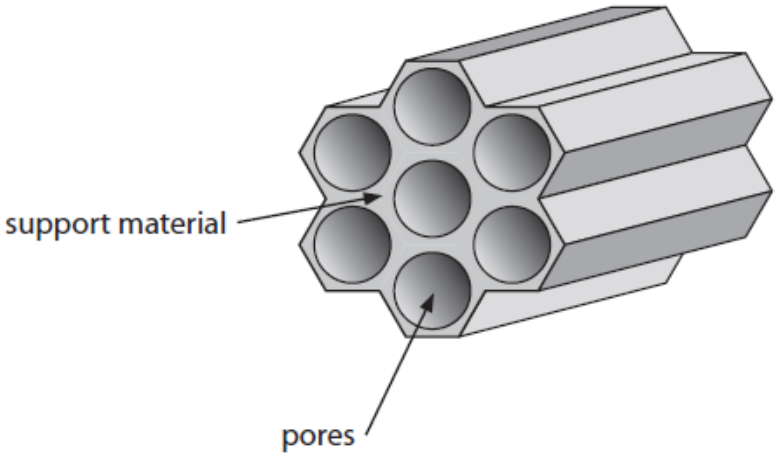
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(f) Catalysts such as phosphoric acid are bonded to a support material that contains lots of pores.



(i) Suggest the advantage of using support materials containing lots of pores.

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(ii) Under these conditions, only about 5 % of the ethene is converted into ethanol as it passes over the catalyst.

Suggest how the overall yield of this process can be improved to make it economically viable.

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(Total for question = 19 marks)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Calcium carbonate reacts with hydrochloric acid.

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

Which factor does **not** affect the rate of this reaction?

☒ **A** concentration

☒ **B** pressure

☒ **C** surface area

☒ **D** temperature

(Total for question = 1 mark)

Q13.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A solution containing 0.100 mol of hydrochloric acid is added to 8.43 g of magnesium carbonate.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) What is the total volume (at r.t.p.) of carbon dioxide formed?

[$Mr(MgCO_3) = 84.3$ Molar volume of a gas at r.t.p. = 24.0 $dm^3\ mol^{-1}$]

(1)

☒ **A** 2.40 dm^3

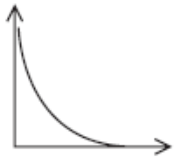
☒ **B** 1.20 dm^3

☒ **C** 2400 dm^3

☒ **D** 1200 dm^3

(b) Which sketch graph shows the volume of carbon dioxide (*y*-axis) plotted against time (*x*-axis) during the reaction?

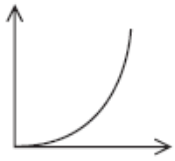
(1)



☒ **A**



☒ **B**

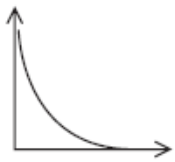


☒ **C**



☒ **D**

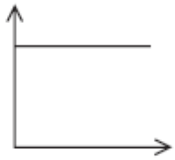
(c) Which sketch graph shows the rate of the reaction (*y*-axis) plotted against time (*x*-axis) during the reaction?



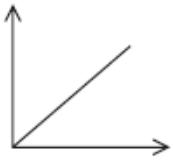
☒ **A**



☒ **B**



☒ **C**



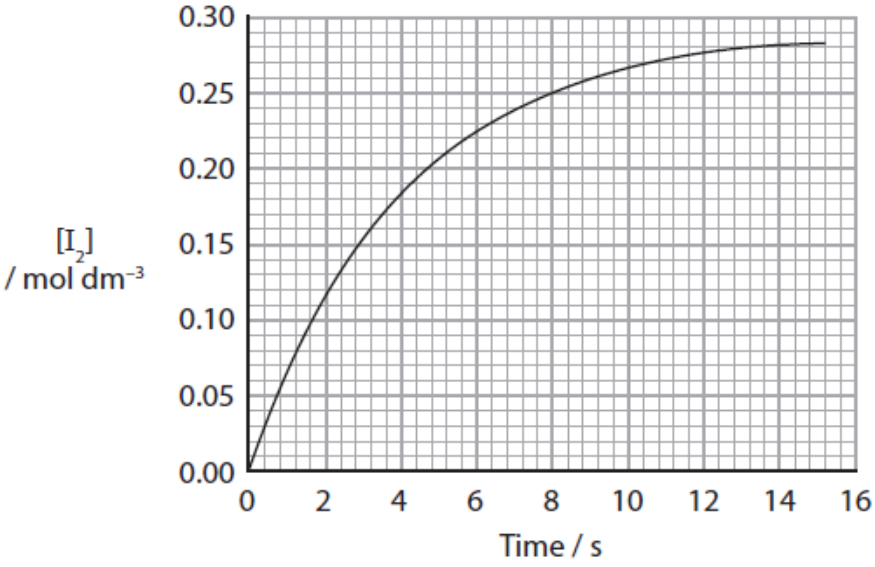
☒ **D**

(Total for question = 3 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows how the concentration of iodine changes with time in a reaction.



What is the value for the rate of reaction, in mol dm^{-3} s^{-1}, at 8 seconds?

☒ **A** 0.01

☒ **B** 0.02

☒ **C** 0.03

☒ **D** 0.25

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q15.

Magnesium metal reacts with hydrochloric acid. Which change in condition would have no effect on the initial rate of this reaction?

(1)

☒ **A** an increase in the volume of acid solution

☒ **B** a decrease in the temperature of the acid solution

☒ **C** an increase in the surface area of the magnesium

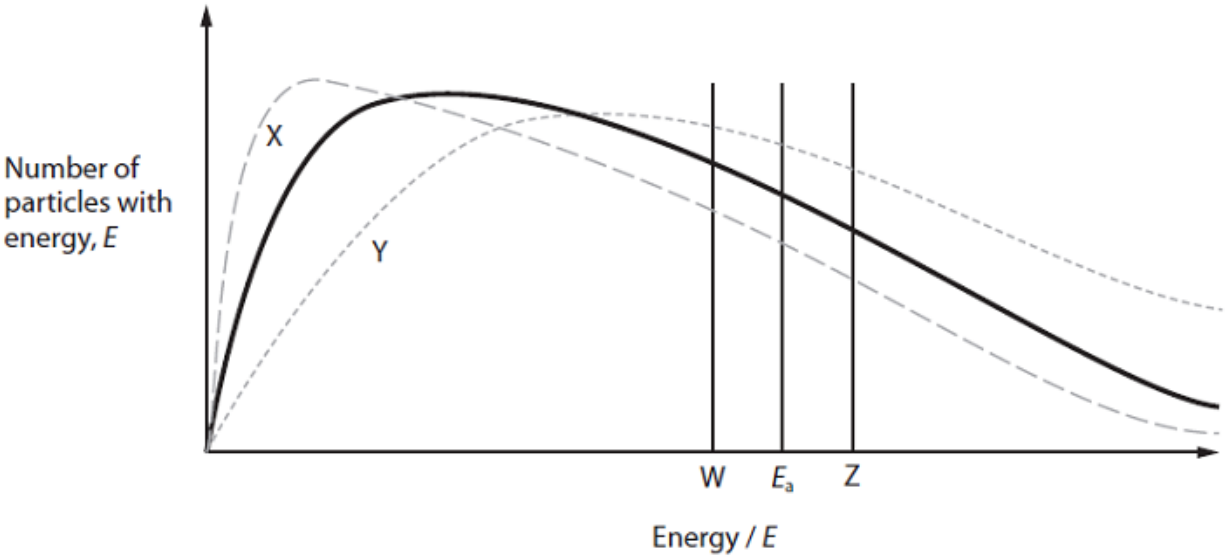
☒ **D** a decrease in the concentration of the acid solution

(Total for question = 1 mark)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The solid line on the graph below shows the Maxwell–Boltzmann distribution for an uncatalysed reaction. E_a is the activation energy of this reaction.



Which row shows the correct Maxwell–Boltzmann curve and activation energy for the reaction at a higher temperature with a catalyst?

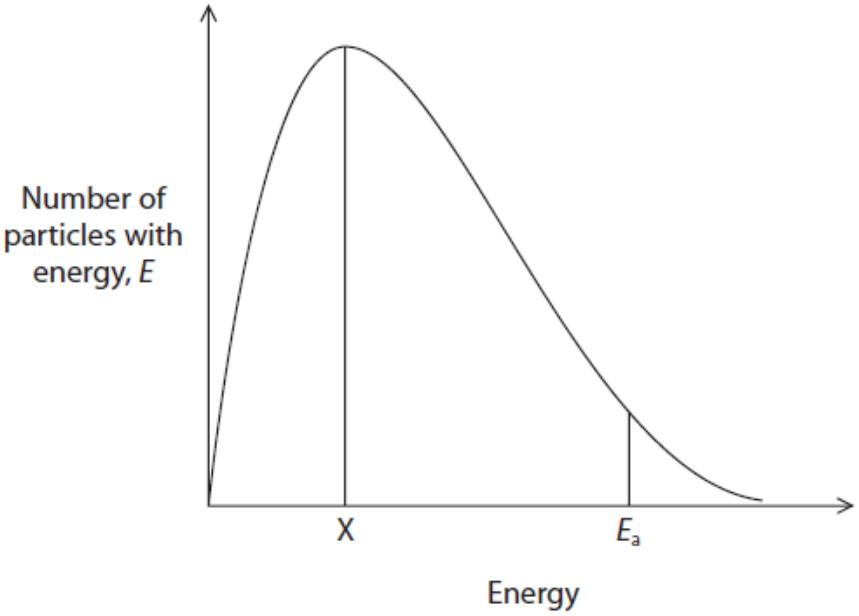
	Maxwell-Boltzmann curve	Activation energy
☒ **A**	X	W
☒ **B**	X	Z
☒ **C**	Y	W
☒ **D**	Y	Z

(Total for question = 1 mark)

Q17.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A Maxwell-Boltzmann distribution curve for the particles present in a reaction mixture is shown.



(a) Which statement is correct?

(1)

☒ **A** position X represents the mean energy of the particles

☒ **B** activation energy, E_a, is the mean energy of the particles that react

☒ **C** the area under the curve to the right of the activation energy, E_a, represents the number of particles with enough energy to react

☒ **D** adding a catalyst moves the activation energy, E_a, to the right

(b) What happens to the distribution curve when the temperature of the gas is **decreased**?

(1)

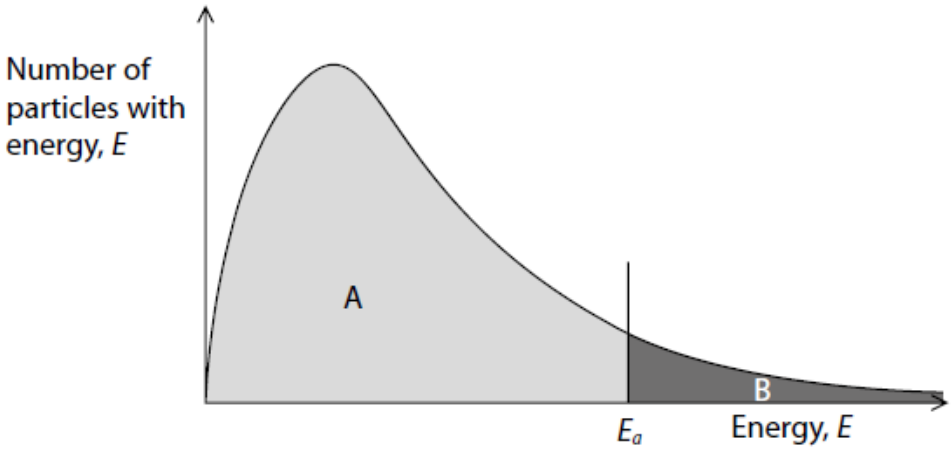
	Position of the peak	Height of the peak
☒ **A**	shifts to the right	lower
☒ **B**	shifts to the right	higher
☒ **C**	shifts to the left	lower
☒ **D**	shifts to the left	higher

(Total for question = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q18.

The diagram shows the general shape of a Maxwell-Boltzmann distribution curve for the particles present in a reaction mixture.



(a) How does the peak change when the temperature of the reaction mixture is decreased?

(1)

	Peak position	Peak height
☒ **A**	shifted left	higher
☒ **B**	shifted right	higher
☒ **C**	shifted left	lower
☒ **D**	shifted right	lower

(b) The activation energy of an uncatalysed reaction is represented by the vertical line, E_a, on the horizontal axis. The shaded areas A and B are the areas under the curve on either side of the line E_a.

How do the two shaded areas change, if at all, when a catalyst is added?

(1)

	Area A	Area B
☒ **A**	increases	decreases
☒ **B**	decreases	increases
☒ **C**	no change	no change
☒ **D**	increases	increases

(Total for question = 2 marks)

Q19.

Potassium chlorate(V), $KClO_3$, is a crystalline solid used in fireworks.

It is produced by the Liebig Process in two stages.

Stage **1** Chlorine gas is passed through hot calcium hydroxide solution forming calcium chlorate(V), $Ca(ClO_3)_2$.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

Stage **2** Potassium chloride solution is then added to form potassium chlorate(V).

$$Ca(ClO_3)_2(aq) + 2KCl(aq) \rightarrow 2KClO_3(aq) + CaCl_2(aq)$$

The solution is heated to reduce its volume and then allowed to crystallise.
The crystals are filtered off.
The remaining filtrate is evaporated further to obtain more crystals.

(a) (i) Write the **overall** equation for the Liebig Process.
State symbols are not required.

(1)

(ii) Calculate the **overall** atom economy by mass for the production of potassium chlorate(V), $KClO_3$, using your equation in (a)(i).

(3)

(b) Explain the type of reaction that takes place in Stage 1 of the Liebig Process, using oxidation numbers.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

(3)

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(c) The crystals of potassium chlorate(V) formed also contain some halide ion impurities.

(i) Describe a chemical test on a solution of these crystals to **confirm** that the impurities present are chloride ions rather than bromide ions. Include the expected results.

(3)

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(ii) 1.52 g of impure potassium chlorate(V), formed in the Liebig Process, was heated until the mass of solid remaining was constant at 1.02 g.

The reaction that occurred was

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

The impurities present did not decompose on heating.

Calculate the percentage purity of the sample.
Give your answer to an appropriate number of significant figures.

(5)

(d) In fireworks, potassium chlorate(V) decomposes. This thermal decomposition takes place in two stages with a solid catalyst.

$$4KClO_3 \rightarrow KCl + 3KClO_4$$

$$KClO_4 \rightarrow KCl + 2O_2$$

(i) Give the systematic name of $KClO_4$.

(1)

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(ii) A student investigated the role of the catalyst in this reaction.

Procedure

Step **1** Heat a sample of $KClO_3$, in a test tube, with a known mass of insoluble catalyst until the mass remains constant.

Step **2** Mix the contents of the test tube with water.

Step **3** Filter the mixture and rinse with deionised water.

Step **4** Dry the remaining solid.

Step **5** Measure the mass of the dry solid.

Explain how each of the steps in this procedure is needed to show that the catalyst is **not** used up in this reaction.

(4)

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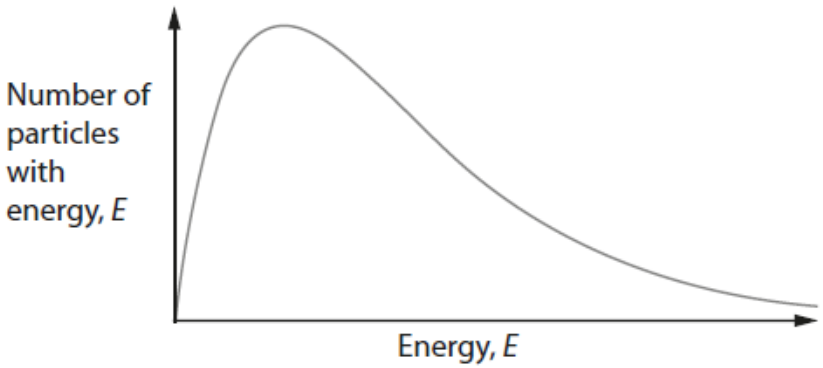
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(e) Explain, using the diagram, how a catalyst speeds up a chemical reaction.

(2)



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(Total for question = 22 marks)

Q20.

Two different processes can be used for the production of chloroethene (CH_2==CHCl), which is the monomer for the manufacture of poly(chloroethene).

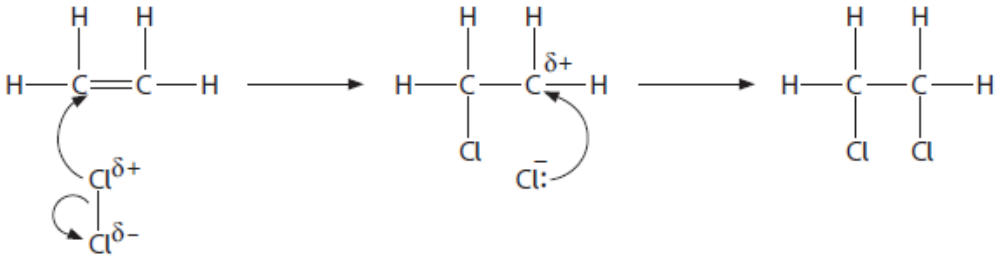
(a) Process **A**

Ethene, produced from crude oil, reacts with chlorine gas to form 1,2-dichloroethane. The 1,2-dichloroethane is then thermally cracked to form chloroethene.

$$C_2H_4(g) + Cl_2(g) \xrightarrow{\text{Reaction 1}} C_2H_4Cl_2(g)$$

$$C_2H_4Cl_2(g) \xrightarrow{\text{Reaction 2}} C_2H_3Cl(g) + HCl(g)$$

(i) A student wrote a mechanism for Reaction 1.



The mechanism contains two mistakes.

Identify each mistake, giving the correction that should be made.

(2)

Mistake 1

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Correction

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Mistake 2

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Correction

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(ii) Write the overall equation for Process **A** and use it to calculate the percentage atom economy by mass for the production of chloroethene.

(3)

(b) Process **B**

In an alternative process, chloroethene is obtained by reacting ethyne (HC≡≡CH), with hydrogen chloride. Ethyne is produced from coal. This reaction uses a catalyst of mercury(II) chloride which is highly toxic.

$$HC{\equiv}CH(g) + HCl(g) \longrightarrow C_2H_3Cl(g)$$

The temperature during this reaction is high enough to vaporise the mercury(II) chloride catalyst.

State how Process **A** compares to Process **B** in terms of the percentage atom economy by mass and environmental impact of each process. No calculation is needed.

(2)

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* (c) Process **B** involves gas molecules reacting at high temperature in the presence of a catalyst.

Explain the effects on the rate of reaction of increasing the temperature and using a catalyst in Process **B**, referring to a labelled diagram of the Maxwell-Boltzmann distribution.

(6)

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(Total for question = 13 marks)

Q21.

The equation for a reversible reaction is shown.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H = -88\,kJ\,mol^{-1}$$

What effect will each change have on the rate of reaction and the equilibrium yield of phosphorus(V) chloride?

(a) Increasing the temperature at constant pressure.

(1)

	Effect on rate of reaction	Effect on yield of $PCl_5(g)$
☐ **A**	increase	decrease
☐ **B**	decrease	decrease
☐ **C**	increase	increase
☐ **D**	decrease	increase

(b) Increasing the pressure at constant temperature.

(1)

	Effect on rate of reaction	Effect on yield of $PCl_5(g)$
☐ **A**	increase	decrease
☐ **B**	decrease	decrease
☐ **C**	increase	increase
☐ **D**	decrease	increase

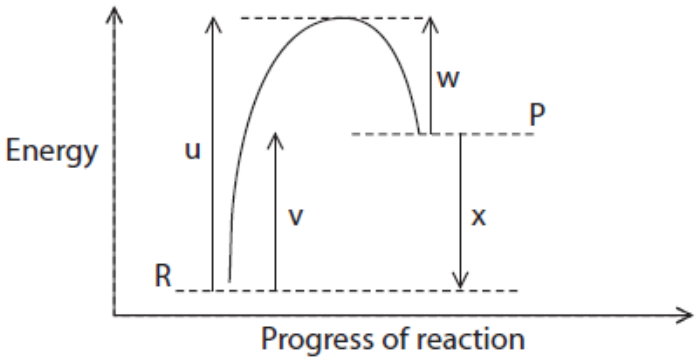
(Total for question = 2 marks)

Q22.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The diagram shows a reaction profile for a reversible reaction.

$$R \rightleftharpoons P$$



(a) Which symbol represents the enthalpy change for the reaction R → P?

(1)

☒ **A** u

☒ **B** v

☒ **C** w

☒ **D** x

(b) Which symbol represents the activation energy of the reaction P → R?

(1)

☒ **B** u

☒ **B** v

☒ **C** w

☒ **D** x

(c) Hess's Law can be applied to this system.

Which expression is correct?

(1)

☒ **A** v + x = u + w

☒ **B** w + x = u

☒ **C** u – w = v

☒ **D** u – v = x

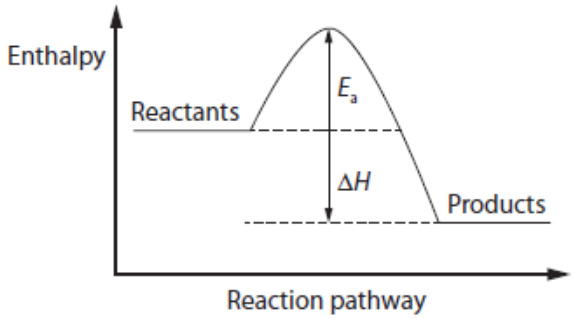
(Total for question = 3 marks)

Q23.

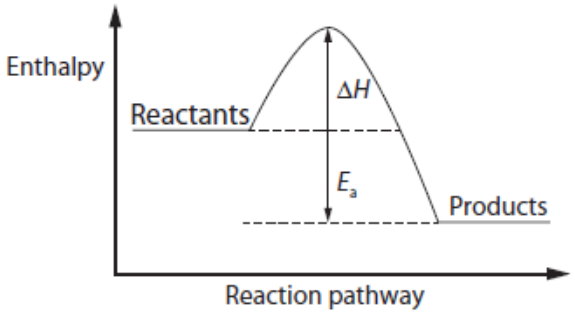
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which is the correctly labelled reaction profile for an exothermic reaction?

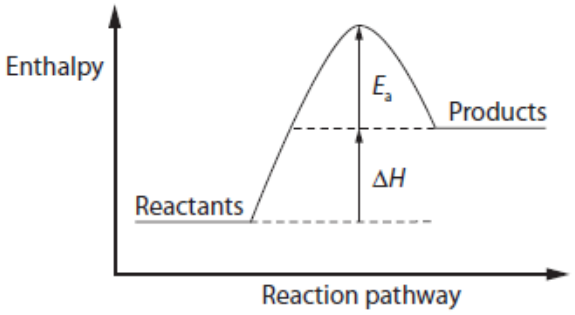
☒ **A**



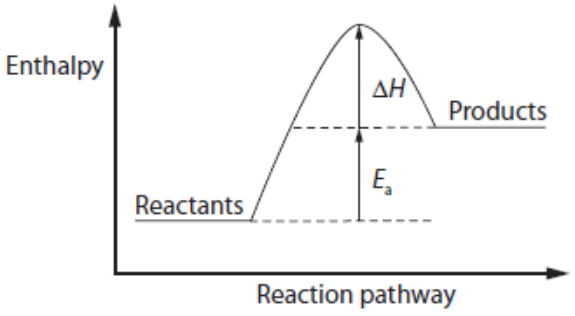
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q24.

Sodium thiosulfate solution reacts with hydrochloric acid to produce solid sulfur.

Which change would be expected to **increase** the time taken for sulfur to appear?

(1)

☒ **A** increasing the concentration of the hydrochloric acid

☒ **B** decreasing the concentration of the sodium thiosulfate

☒ **C** increasing the temperature

☒ **D** adding a catalyst

(Total for question = 1 mark)

Q25.

This question is about sulfuric acid.

(a) Sulfuric acid is manufactured in a three-step process.

Step **1** $S(s) + O_2(g) \rightarrow SO_2(g)$

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

Step **3** $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

(i) At room temperature and pressure, sulfur is a solid and oxygen a gas.

Explain why sulfur and oxygen exist in different states by referring to the intermolecular forces involved.

(2)

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(ii) Step **2** is a reversible reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

State the effect on the position of equilibrium when the temperature and pressure are increased. Justify your answers.

(4)

Increasing temperature at constant pressure

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Increasing pressure at constant temperature

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(iii) Vanadium(V) oxide, V_2O_5, is used to catalyse the reaction in Step **2**.

Complete the reaction profile to show both the catalysed and uncatalysed reactions.
Label the activation energy and the enthalpy change. Your diagram does not have to be to scale.

(4)



(iv) Explain how the use of a catalyst makes this reaction more sustainable.

(2)

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* (b) Concentrated sulfuric acid reacts with solid potassium chloride and with solid potassium iodide.

Compare and contrast these reactions to show the difference in reducing ability of these two halide ions.
In your answer describe what would be observed and identify the products formed.

(6)

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(c) Dilute sulfuric acid is used in many laboratories. It is often supplied as concentrated sulfuric acid and then diluted.

A technician makes 500 cm^3 of 1.5 mol dm^{-3} sulfuric acid by adding 40.5 cm^3 of concentrated sulfuric acid to distilled water.

Calculate the concentration of the **concentrated** sulfuric acid, in mol dm^{-3} .

(2)

(Total for question = 20 marks)

Q26.

Propanoic acid, CH_3CH_2COOH, is a colourless liquid used as a preservative in animal feed.
Propanoic acid can be formed by oxidising the alcohol propan-1-ol.

(a) Write the balanced equation for the oxidation of propan-1-ol to form propanoic acid.

Use [O] to represent the oxygen from the oxidising agent.
State symbols are not required.

(1)

*(b) Propan-1-ol is heated with a concentrated solution of acidified potassium dichromate(VI).

Explain how the conditions used affect the rate of the reaction **and** ensure that propanoic acid is the only organic product.

(6)

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(c) A student suggested using universal indicator to check for the presence of propanoic acid formed in the reaction mixture.

Give a reason why the result of this test is **not** likely to be conclusive.

(1)

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(d) The permitted mass of propanoic acid used in animal feed is in the range 1000–3000 mg kg^{-1}. A titration method may be used to check the concentration of propanoic acid in animal feed.

A 50.0 cm^3 sample of propanoic acid solution was extracted from 50 g of an animal feed.
The sample was added to a volumetric flask and the volume made up to 250.0 cm^3 and mixed thoroughly. A pipette was used to transfer 25.0 cm^3 of the diluted acid into a conical flask containing an indicator.

The contents of the conical flask were titrated with a solution of sodium hydroxide, NaOH(aq), with concentration 0.00668 mol dm^{-3}.

The procedure was repeated twice and the results obtained are shown.

	Run 1	Run 2	Run 3
Titre / cm^3	23.20	22.10	22.20

(i) Phenolphthalein is a suitable indicator for this titration.

State the colour **change** at the end-point.

(2)

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(ii) Suggest **two** possible reasons why the titre for Run 1 is greater than the other two titres.

(2)

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(iii) The equation for the reaction of propanoic acid with sodium hydroxide is

$$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$$

Calculate the mass in grams of propanoic acid extracted from the animal feed.

Give your answer to an appropriate number of significant figures.

(5)

(iv) Use your answer to (d)(iii) to determine whether the acid in this sample lies within the permitted range for use in animal feed.

(2)

(v) Suggest how the animal feed would be affected if the amount of propanoic acid was outside the permitted range.

(1)

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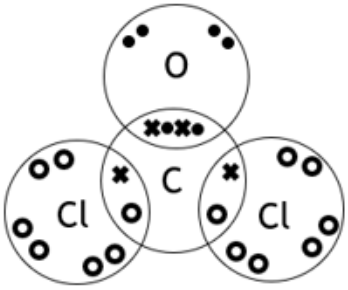
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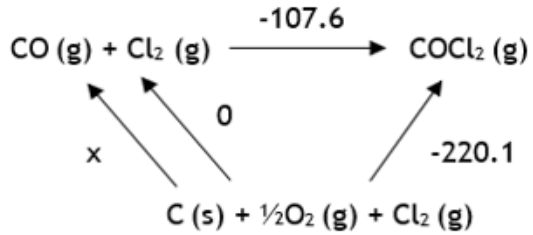
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Mark Scheme

Q1.

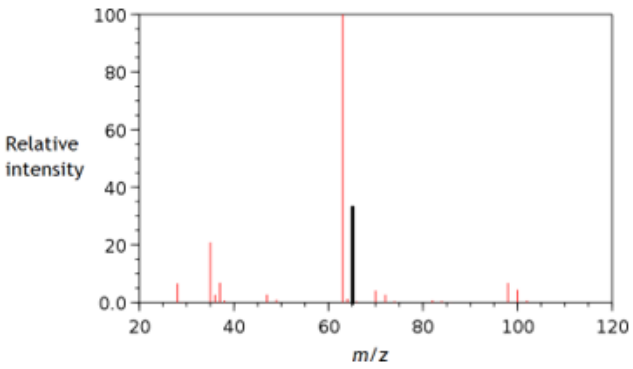
Q	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: A diagram that includes: • carbon singly covalently bonded to two chlorine atoms and three lone pairs on each chlorine **(1)** • carbon doubly bonded to an oxygen atom and two lone pairs on the oxygen **(1)**	 Penalise lack of lone pairs once only Allow any representation of electrons Allow individual electrons spread out, rather than in pairs Allow horizontal shared pairs of electrons Ignore lines representing covalent bonds	**2**

Q	Answer	Additional Guidance	Mark
(b)(i)	An explanation that makes reference to the following points: Any two pairs from the three: • decrease the temperature **(1)** • as the (forward) reaction is exothermic **(1)** • increase the pressure **(1)** • as there a fewer moles of (gas) on the product side **(1)** **EITHER** • remove the phosgene (as it is formed) **(1)** • to reduce the concentration of product (so equilibrium moves to the right) **(1)** **OR** • add more CO / Cl_2 **(1)** • to increase the concentration of the reactants (so equilibrium moves to the right) **(1)**	Ignore references to rate of reaction Allow T↓ Allow "favours the exothermic reaction" Allow P↑ if numbers are quoted, they must be 2:1 Allow "favours the side with fewer moles"	**4**

Q	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • correct species **(1)** • correct state symbols **(1)** • correct arrows **(1)** • calculation of value **(1)**	Example of an answer:  ΔH_f CO = −220.1 – (−107.6) = −112.5 (kJ mol^{-1}) Accept state symbol for C(s, graphite) Ignore absence of arrow and value to chlorine Numbers are not required on the cycle	**4**

Q	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • chlorine isotopes (35 and 37) are in the ratio of 3:1 **(1)** • (as there are) two chlorine atoms give the ratio of 9:6:1 **(1)**	Accept ^{37}Cl 75% : ^{35}Cl 25% Allow this shown in workings e.g. $CO^{37}Cl^{37}Cl^{(+)}$ = 102, $CO^{35}Cl^{37}Cl^{(+)}$ = 100, $CO^{35}Cl^{35}Cl^{(+)}$ = 98 Do not award ^{36}Cl Mark independently Reference to isotopes of carbon should be penalised once	**2**

Q	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following point • $CO^{35}Cl^{+}$	Allow the + on any of the atoms Ignore brackets	**1**

Q	Answer	Additional Guidance	Mark
(c)(iii)	An answer that makes reference to the following point • peak drawn at 65 with relative intensity of 33.3	Example of completed graph:  Allow a peak height between 30-35	**1**

Q	Answer	Additional Guidance	Mark
(d)	An answer that makes reference to the following points: • 1795 (cm^{-1}) **(1)** • (from the) C=O (stretching vibrations) **(1)**	Allow a number or range within 1630-1850 (cm^{-1}) M2 is dependent on M1 Allow a number or range within 550-850 (cm^{-1}) **and** C-Cl (stretching vibrations) for 2 marks Ignore acyl chloride Do not award M2 for aldehydes/ketones	**1**

Q	Answer	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following point: • balanced equation	$2CHCl_3 + O_2 \rightarrow 2COCl_2 + 2HCl$ Accept multiples of the equation Ignore state symbols even if incorrect	**1**

Q	Answer	Additional Guidance	Mark
(e)(ii)	An answer that makes reference to the following point: • oxygen concentration will decrease	Allow oxygen used up Allow [O_2] decreases Allow volume of oxygen decreases Do not award "air is used up" "Reactants are used up" is insufficient as doesn't apply information from the question Comments about trichloromethane decreasing negate the oxygen mark	**1**

Q	Answer	Additional Guidance	Mark
(e)(iii)	An answer that makes reference to the following point • use a fume cupboard (due to toxic and irritant gases)	Allow open in a well-ventilated laboratory / open outside / wear a **gas** mask Ignore eye protection / laboratory coats / gloves Ignore just "mask" and "do not inhale" Do not award face shield	**1**

Q	Answer	Additional Guidance	Mark
(e)(iv)	An answer that makes reference to the following points: • no, because some of the HCl/$COCl_2$ may have dissolved into the chloroform / be trapped as bubbles in the liquid	Allow may have reacted (with oxygen) to give (toxic) phosgene / $COCl_2$	**1**
		(Total for Question = 20 marks)	

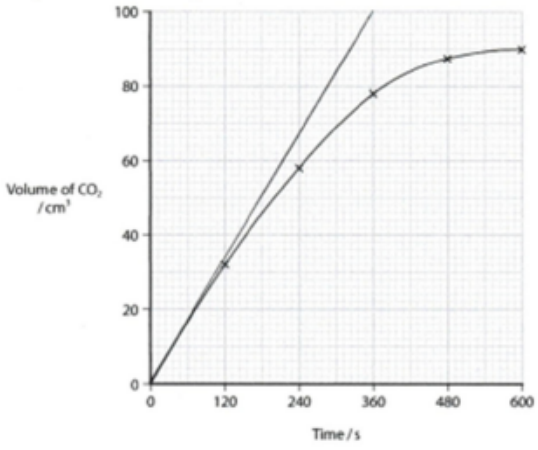
Q2.

Question Number	Answer	Mark
	The only correct answer is A (0.75) ***B** is not correct because this is the reciprocal of the correct answer* ***C** is not correct because this is the total volume at 40 seconds divided by 40* ***D** is not correct because this is the initial rate*	1

Q3.

Question Number	Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • **Size (and charge)** calcium ion / Ca^{2+} has a larger (ionic) radius than a magnesium ion (but the same charge) **or** magnesium ion / Mg^{2+} has a smaller (ionic) radius / is smaller than a calcium ion (but the same charge) **(1)** • **Polarising power** so calcium ion / Ca^{2+} causes less polarisation / distortion **or** magnesium ion / Mg^{2+} causes more polarisation / distortion **(1)** • **What is polarised** of the carbonate ion / CO_3^{2-} / anion / negative ion / C–O bonds / C=O bonds /CO bonds **(1)**	Penalise omission of 'ion' or just magnesium / Mg / calcium / Ca without charge once only in M1 and M2 Allow reverse argument for magnesium ions in M1 and M2 Allow size for radius or just 'bigger / smaller' Allow ionic radius / size of cation increases down the group / decreases up the group Allow calcium carbonate has a larger **cation** Allow calcium ions have a lower charge density Allow calcium ions have more shells of electrons Ignore effective nuclear charge / mass : charge ratio Ignore atomic radius Ignore omission of same charge Do not award M1 if mention of different / incorrect charges on magnesium and calcium ions Allow polarising power of cation decreases down the group Allow Ca^{2+} causes less weakening of bonds for polarisation Do not award just 'the carbonate ion is less polarisable' for M2, although this can score M3 Allow electron cloud for ion Do not award reference to nitrate / N-O bonds Do not award reference to breaking unspecified bonds / (ionic) bond between cation and anion Do not award references to intermolecular forces	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of mol of CO_2 (1) • calculation of mol of HCl (1) • calculation of volume of HCl **and** corresponding volume unit (1)	Example of calculation: mol CO_2 = $\frac{100}{24\,000}$ = 0.0041667 / 4.1667 x 10^{-3} (mol) mol HCl = 2 x 0.0041667 = 0.0083333 / 8.3333 x 10^{-3} (mol) TE on M1 vol HCl = $\frac{0.0083333}{0.500}$ x 1000 = (16.667) = 16.6 cm^3 / 0.0166 dm^3 Do not award incorrect units e.g. cm^{-3} / dm^{-3} Allow 16.67 / 16.7 cm^3 as the theoretical volume of CO_2 is 100.02 / 100.2 cm^3 Do not award 17 cm^3 as the theoretical volume of CO_2 is 102 cm^3 so would exceed the measurable volume of the syringe Allow any number between 16 and 16.7 cm^3 / 0.016 and 0.0167 dm^3 inclusive TE on M2 Ignore SF except 1 SF Correct answer with units and no working scores (3) Accept fractions / correct working not evaluated for M1 and M2 e.g. 1/240, 1/120	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)		Example of working:  	(3)
	• tangent drawn at t = 0	Tangent must touch the curve for at least 24 s (2 small squares horizontally) and extend to at least 20 cm^3	
	• gradient	Gradient = $\frac{100}{360}$ = 0.27778 (expected value 0.25 to 0.33 for tangent at t = 0) TE on tangent drawn at any time value If no tangent drawn, allow a selected point and y/x value e.g. 32/120 = 0.27	
	• units	Stand alone mark $cm^3\ s^{-1}$ or cm^3 / s or $\frac{cm^3}{s}$ Allow $cm^3\ s^-$	

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following point: • initial rate halves **and** final volume of CO_2 halves / is 45 (cm^3)	Allow initial rate decreases **and** final volume of CO_2 decreases Do not award any specific decrease (e.g. decrease by a factor of 4) except for half	(1)

Q4.

Question number	Answer	Mark
	The only correct answer is D (64) ***A*** *is not correct because it assumes the relationship between temperature and rate is linear* ***B*** *is not correct because it suggests a rate increase of 6 x 2* ***C*** *is not correct because it suggests a rate increase of 6^2 instead of 2^6*	**(1)**

Q5.

Question number	Answer	Mark
	The only correct answer is B (d ÷ a) *A is not correct because it is not a gradient of a tangent and is inverse of the rate* *C is not correct because it is the average rate* *D is not correct because it is the initial rate*	**(1)**

Q6.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An explanation that makes reference to the following points: EQUILIBRIUM • there are more (gaseous) moles/molecules on LHS / less (gaseous) moles on RHS **(1)** • (so high pressure) moves equilibrium to RHS / increases yield of methanol **(1)** OR KINETIC • an increase in pressure increases the number/rate of collisions (of molecules) **(1)** • (So) increases the rate of reaction **(1)**	NOTE If two marks are scored they must be derived from either the kinetic or equilibrium explanations. If both explanations are used any incorrect statement negates one mark. Any reference to atoms scores 0 for M1 If numbers of moles given, they must be correct M2 depends on M1 for both explanations	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • the (forward) reaction is exothermic **(1)** • a lower temperature would increase the yield /move equilibrium to RHS or reverse argument **(1)** • a (compromise) temperature is used to ensure the rate is fast enough (without the equilibrium position moving too far to the LHS) ALLOW (increased/high/stated) temperature increases the rate of reaction **(1)**	Note: if (forward) reaction is identified as endothermic then neither M1 nor M2 can be scored Ignore references to cost/economics/ environmental	**(3)**

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	An explanation that makes reference to one of the following points: (a catalyst) allows a lower temperature to be used / less energ is needed (1) (a copper catalyst is specific for methanol) so there is less waste/fewer other products/improves atom economy (1) (a catalyst) is not used up/can be used again (1)	Ignore just increases rate/ lowers activation energy	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(i)	Reagents • sodium / potassium dichromate ((VI)) / $Na_2Cr_2O_7$/$K_2Cr_2O_7$/ $Cr_2O_7^{2-}$ **and** acidified / H+ / sulfuric acid (1) Reaction conditions • (Heat under) **reflux** (1)	Do not award potassium manganate(VII) M2 dependent on M1 or near miss	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	$CH_3OH + 2[O] \longrightarrow HCOOH + H_2O$ (1)	Allow; CH_2O_2,CHOOH,HCO_2H	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	Functional group test add any carbonate /hydrogencarbonate OR add magnesium (powder/ribbon) (1) OR addition of any alcohol (and strong acid to form an ester) Positive result (1) effervescence / bubbles / gas given off (turns lime water cloudy OR burns with a "pop") OR Fruity smell	Do not award the addition of Na or PCl_5 Ignore reference to indicator M2 depends on M1 or near miss	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(iv)	• infra red absorption at 3750 - 3200 cm^{-1} /3300 cm^{-1} due to O-H of alcohol/methanol **(1)** • infra red absorption at 1725 - 1700 cm^{-1} /1700 cm^{-1} due to C=O group (of carboxylic acid/methanoic acid) **(1)** • peaks due to methanol/alcohol would disappear/be absent **(1)**	Allow the peak at 1020 for methanol in the fingerprint region Accept infra red absorption at 3300 - 2500 cm^{-1} /2500 cm^{-1} showing O-H group of COOH Allow the fingerprint region would change Penalise use of OH^-/-OH once only. In M1 and M2 penalise absence of bonds once only	**(3)**

Question Number	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to two of the following points: • burning (petrol/methanol/fuel) produces CO_2 /greenhouse gases/contributes to global warming **(1)** • the methanol is made from captured CO_2 / is made from CO_2 that would have been released anyway **(1)** • the increase in global temperatures will be reduced **(1)**	IGNORE references to ozone depletion Do not award : methane is produced	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• 352g carbon dioxide (released per mole octane) **(1)**	Example calculation: 8 x 44 = 352 (g)	**(1)**

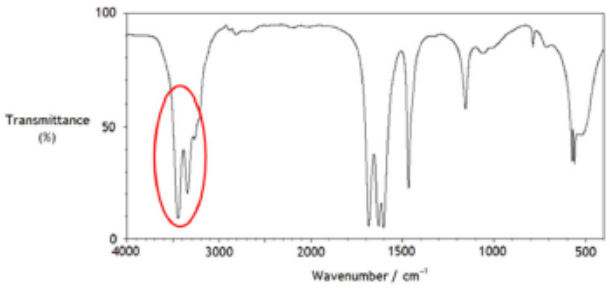
Question Number	Answer	Additional Guidance	Mark
(c)(iii)	• Mass petrol reduction per year **(1)** • Mass CO_2 reduction **(1)** OR • Moles of petrol used per year **(1)** • 5% reduction in CO_2 **(1)** OR • 5% reduction in moles of petrol used per year **(1)** • Mass CO_2 produced **(1)**	Example of calculation: 1200 x 0.05 = 60 (kg) 60 ÷ 114 x 352 = 185.26 kg (1200 x 1000) ÷ 114 = 10526 (moles) 352 x 10526 x 5 ÷ 100 = 185260 g = 185.26 kg 1200 x 1000 x 0.05 ÷ 114 = 526.3 (moles) 526.3 x 352 ÷ 1000 = 185.26 kg IGNORE SF except 1 SF correct answer with no working scores 2	**(2)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • urea forms hydrogen bonds **(1)** • urea forms (permanent) dipole-dipole forces **(1)** • these forces are stronger than London forces **(1)**	Ignore references to number of hydrogen bonds Allow a correct diagram Allow hydrogen bonds are the strong**est** intermolecular forces Allow dispersion forces/van der Waals for London forces Do not award M3 if breaking covalent bonds is referenced	**(3)**

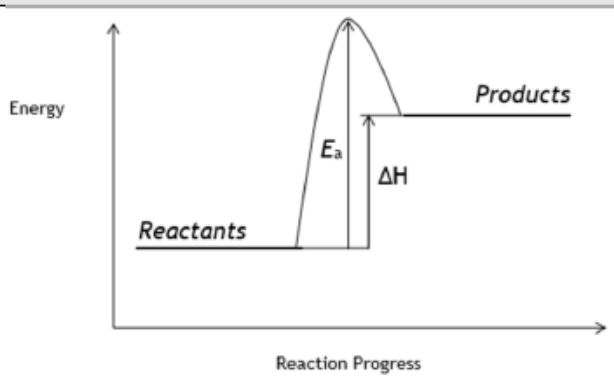
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • M_r of urea **(1)** OR moles of urea • mass of urea required **(1)**	M_r = 60 (9.07 ÷ 1000) × 150 = 1.36(05) (9.07 ÷ 1000) × 150 × 60 = 81.63 (g) / 81.6 (g) Ignore SF except 1 SF Correct answer scores (2) No M2 if units other than grams are used	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • (oxides of nitrogen lead to the formation of) acid rain	Allow formation of photochemical smog Allow "NO can react with ozone" Allow descriptions of acid rain formation e.g. forms HNO_3 Do not award greenhouse effect / global warming Do not award depletes the ozone layer without reference to nitrogen(II) oxide/NO	**(1)**

Question Number	Answer	Additional Guidance	Mark
(d)(i)	An answer that makes reference to the following point • correct peak circled	Example of completed spectra:  Allow any number of the three peaks in the region to be circled individually Extra circles negate the mark	**(1)**

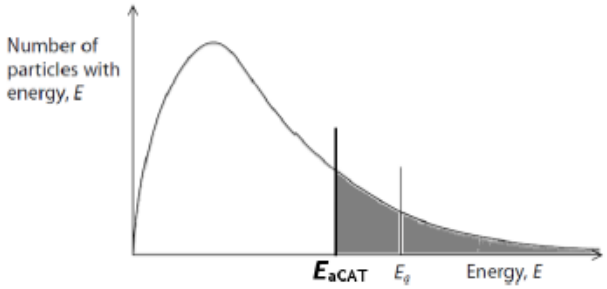
Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following point • C=O		**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following points • products **and** reversible arrow	Example of balanced equation: $\rightleftharpoons 2NH_3 + CO_2$ Accept products in any order Allow multiples if equation is balanced Allow 2 full headed arrows, one in either direction	**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	An answer that makes reference to the following points: • line labelled products higher than line labelled reactants and to the right **(1)** • ΔH labelled correctly **(1)** • E_a labelled correctly **(1)**	 Accept actual reactants and products labelled on diagram (even if slightly incorrect names or formulae are used) Ignore state symbols even if incorrect Allow ΔH given as +133 Double-headed arrows penalised once only Arrows in wrong direction or missing heads penalised each time M2 and M3 can be given as a TE on exothermic reaction if arrows are consistent	**(3)**

Question Number	Answer	Additional Guidance	Mark
(f)(i)	An explanation that makes reference to the following points: • the urea is a reactant and forms a new product (that leaves the catalytic converter)	Allow "catalysts are not used up in the reaction" Allow "urea is used up in the reaction" Allow "the amount/mass of urea changed" Allow "urea is not reformed" Allow "the catalyst is a metal oxide" Ignore references to activation energy / rate / reusable Do not award "catalysts do not react"	**(1)**

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Question Number	Answer	Additional Guidance	Mark
(f)(ii)	An explanation that makes reference to the following points: • catalyst decreases the activation energy required **(1)** • more particles have the energy required for the reaction to take place **(1)** • increases the number of successful collisions per unit time / frequency of successful collisions **(1)**	Example of a completed diagram  Accept M1 shown on the diagram Allow "Ea moves to the left" Allow area under the curve above Ea increases for M2 NOTE: Shading is not required, but incorrect shading would negate M2	**(3)**

Question Number	Answer	Additional Guidance	Mark
(g)(i)	• hot gases from the engine warm up the catalytic converter	Allow uses the (heat) energy from the engine Allow energy from combustion of fuel Allow the reactions that occur in the catalytic converter are exothermic	**(1)**

Question Number	Answer	Additional Guidance	Mark
(g)(ii)	• conversion of m^3 to dm^3 **(1)** • moles of nitrogen **(1)** • number of molecules of nitrogen **(1)**	An example of a calculation: 89.3 × 1000 = 89300 dm^3 89300 ÷ 51.1 = 1747.6 / 1748 mol 1748 × 6.02 × 10^{23} = 1.052 ×10^{27} / 1.05 ×10^{27} / 1.1 ×10^{27} Allow TE throughout Ignore SF except 1SF Ignore units even if incorrect 1.052 ×10^{24} / 1.05 ×10^{24} / 1.1 ×10^{24} scores 2 1.052 ×10^{21} / 1.05 ×10^{21} / 1.1 ×10^{21} scores 2 2.747 ×10^{30} / 2.75 ×10^{30} / 2.8 ×10^{30} scores 2 Correct answer with some working scores (3)	**(3)**

Q8.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (disproportionation) ***A*** *is incorrect because no species has been replaced/displaced* ***C*** *is incorrect because no species has been eliminated* ***D*** *is incorrect because water is produced and no species is hydrolysed*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is B** (4.2 x 10^{-5} mol s^{-1}) ***A*** *is incorrect because incorrect units for the Molar Volume of a gas has been used* ***C*** *is incorrect because the stoichiometry has not been taken into account* ***D*** *is incorrect because the stoichiometry is incorrect*	**(1)**

Q9.

Question number	Answer	Mark
(a)	**The only correct answer is D** (decreasing the activation energy of the reaction) ***A*** *is incorrect because only an increase in temperature causes the average kinetic energy of the molecules to increase* ***B*** *is incorrect because only a decrease in temperature causes the average kinetic energy of the molecules to decrease* ***C*** *is incorrect because if the activation energy increased, the rate of decomposition would decrease*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is D** (0.833 (mol dm^{-3})) ***A*** *is incorrect because the volume of oxygen has not been converted into moles* ***B*** *is incorrect because the 2 : 1 mole ratio has been used the wrong way around* ***C*** *is incorrect because the 2 : 1 mole ratio has not been used*	(1)

Q10.

Question Number	Correct Answer	Mark
	The only correct answer is A (X) ***B*** *is incorrect as Y represents the activation energy of the reverse reaction* ***C*** *is incorrect as X-Y is the enthalpy change for the reaction* ***D*** *is incorrect as X+Y is the sum of the activation energies*	**1**

Q11.

Question Number	Answer	Additional Guidance	Mark
(a)	A description that makes reference to the following points: • advantage: (it is produced from) renewable / sustainable (resources) **or** it produces fewer emissions (of CO_2 / greenhouse gases) (1) • disadvantage: it uses up land (that could be used for food production)/uses a food crop that could be eaten **or** it produces less energy (per mole / g) (1)	Do not award no greenhouse gases Ignore cleaner fuel/ more efficient combustion Ignore reference to engine modifications/carbon neutrality/using less oil/good for the environment Ignore just ' it uses lots of crops' Ignore references to time to grow crops/time to carry out fermentation/cost Ignore produces CO_2 Do not award any references to ozone depletion	(2)

Question Number	Answer	Additional Guidance	Mark
(b)	• **ethanol** can be oxidised	Allow **ethanol** can react with oxygen Allow possible (organic) products of oxidation e.g. carboxylic acid / ethanoic acid / aldehyde / ethanal Ignore just 'oxidation takes place' or 'it can be oxidised' Allow to ensure only anaerobic respiration takes place. Allow aerobic respiration would take place (in the air) (producing water and carbon dioxide) Do not award yeast reacts with oxygen Do not award to prevent combustion/ethanol would burn	(1)

Question Number	Answer	Additional Guidance	Mark
(c)	• (fractional) distillation	Allow distil the mixture	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(i)	• ethanol forms hydrogen bonds (with water)	Ignore both are polar/ they are miscible Ignore comments about solubility/like dissolves like	(1)

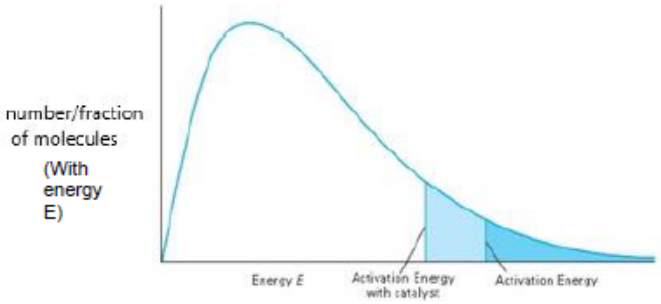
Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to one of the following points: • (water can cause) corrosion / rusting • reduce the energy efficiency of the engine/fuel/ethanol • causes phase separation of the fuel	Ignore damages the engine Allow water does not burn/ fewer km per l / miles per gallon Allow just 'reduced efficiency' Ignore references to ethanol being diluted	(1)

Question Number	Answer	Additional Guidance	Mark
* (e)(i)	This question assesses the student's ability to show a coherent and logically structured Answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the Answer is structured and shows lines of reasoning. The following table shows how the Marks should be awarded for indicative content. Number of indicative Marking points seen in Answer / Number of Marks awarded for indicative Marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 The following table shows how the Marks should be awarded for structure and lines of reasoning. Number of Marks awarded for structure of Answer and sustained lines of reasoning	Guidance on how the Mark scheme should be applied. The Mark for indicative content should be added to the Mark for lines of reasoning. For example, a response with five indicative Marking points that is partially structured with some linkages and lines of reasoning scores 4 Marks (3 Marks for indicative content and 1 Mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative Marking points would yield an overall score of 3 Marks (3 Marks for indicative content and no Marks for linkages).	(6)

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	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2		In general it would be expected that 5 or 6 indicative points would get 2 reasoning Marks, and 3 or 4 indicative points would get 1 Mark for reasoning, and 0, 1 or 2 indicative points would score zero Marks for reasoning. If there is any incorrect chemistry, deduct Mark(s) from the reasoning. If no reasoning Mark(s) awarded do not deduct Mark(s).	
	Answer is partially structured with some linkages and lines of reasoning	1			
	Answer has no linkages between points and is unstructured	0			
	Indicative content **IP1** if temperature increases, **rate** increases (because more particles have energy greater than E_a) **IP2** if temperature increases, yield decreases (because forward reaction is exothermic/ reaction moves in the endothermic direction) **IP3** if pressure increases, rate increases (because particles are more crowded and) collision frequency increases) **IP4** if pressure increases, yield increases(as there are fewer particles on the RHS of the equation)				

	IP5 the catalyst allows the use of lower temperature/less energy (for the same rate) **IP6** high pressure (and temperature) are very expensive	Allow reaction shifts to the left as an alternative to decreases yield Allow reaction shifts to the right as an alternative to increase yield Ignore fewer atoms on the RHS Ignore any reference to how the catalyst works and the effect of catalyst on rate and yield Allow conditions used are compromise between yield **and** cost / rate **and** cost Allow reverse argument for all points	

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	An explanation that makes reference to the following points: (1) • correct labelling of both axes. (1) • activation energy labelled (1) • activation energy with a catalyst shown to the left of the uncatalysed activation energy. (1)	 M1, M2 and M3 shown on the diagram Both Ea and the catalysed Ea must be to the right of the peak and on the same curve if another temp curve is drawn M4 can be shown on the diagram with labelled shading Allow more particles have activation energy Do not award catalyst increases yield / particles have more energy/ particles move faster/ greater collision frequency Ignore more frequent successful collisions	(4)

	• more particles have energy greater than the activation energy with the catalyst / more particles to the right of the activation energy / greater area to the right of the activation energy		

Question Number	Answer	Additional Guidance	Mark
(f)(i)	• large(r) surface area (so faster rate of reaction)	Accept more (active) sites Allow more / greater surface Ignore greater area / area of contact	(1)

Question Number	Answer	Additional Guidance	Mark
(f)(ii)	A description that makes reference to the following points: • remove the ethanol (1) • recycle the (unused) reactants (1)	Accept condense the ethanol Allow remove the ethanol to shift the eqm to the right scores (2) Ignore any reference to temperature, pressure or catalyst Ignore any reference to adding more reactants	(2)

Q12.

Question number	Answer	Mark
	The only correct answer is B (pressure) ***A*** *is not correct because concentration of the acid does affect the rate of reaction* ***C*** *is not correct because surface area of the solid does affect the rate of reaction* ***D*** *is not correct because temperature does affect the rate of reaction*	**(1)**

Q13.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (1.20 dm^3) ***A*** *is incorrect because the limiting factor of the hydrochloric acid has been neglected* ***C*** *is incorrect because the limiting factor of the hydrochloric acid has been neglected and the answer would be correct if the units were* cm^3 ***D*** *is incorrect because the answer would be correct if the units were* cm^3	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is B**  ***A*** *is incorrect because the volume of gas is shown decreasing with time* ***C*** *is incorrect because the gradient is shown increasing with time* ***D*** *is incorrect because the gradient is shown as constant*	(1)

Question Number	Answer	Mark
(c)	**The only correct answer is A**  ***B*** *is incorrect because the rate is shown increasing with time* ***C*** *is incorrect because the rate is shown as constant* ***D*** *is incorrect because the rate is shown increasing with time*	(1)

Q14.

Q	Answer	Mark
	The only correct answer is A (0.01) ***B*** *is incorrect because this is the average rate of reaction over 15 seconds* ***C*** *is incorrect because this is the average rate of reaction up to 8 seconds* ***D*** *is incorrect because this is the concentration reading at 8 seconds*	**1**

Q15.

Question number	Answer	Mark
	A an increase in the volume of acid solution	1

Q16.

Q	Answer	Mark
	The only correct answer is C (Y and W) ***A*** *is incorrect because the curve is for a lower temperature* ***B*** *is incorrect because the curve is for a lower temperature and the* E_a *has increased* ***D*** *is incorrect because the* E_a *has increased*	**1**

Q17.

Question Number	Answer	Mark
(a)	**The only correct answer is C** (the area under the curve to the right of the activation energy, E_a represents the number of particles with enough energy to react) ***A*** *is not correct because this is the mode energy of the particles* ***B*** *is not correct because the activation energy is the minimum energy required for a reaction to take place* ***D*** *is not correct because a catalyst would move the activation energy to the left*	1

Question Number	Answer	Mark
(b)	**The only correct answer is D** (shifts to the left, higher) ***A*** *is not correct because the curve would shift to the left and the peak would be higher* ***B*** *is not correct because the curve would shift to the left* ***C*** *is not correct because the peak would be higher*	1

Q18.

Question number	Answer	Mark
(a)	A peak position shifted left, peak height higher	1

Question number	Answer	Mark
(b)	B area A decreases, area B increases	1

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$3Ca(OH)_2 + 3Cl_2 + KCl \rightarrow KClO_3 + 3CaCl_2 + 3H_2O$ OR $6Ca(OH)_2 + 6Cl_2 + 2KCl \rightarrow 2KClO_3 + 6CaCl_2 + 6H_2O$	Allow multiples If multiple used allow '$CaCl_2$ +5$CaCl_2$' Ignore state symbols	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• calculation of M_r of $KClO_3$ **(1)** • calculation of M_r of all products / reactants **(1)** • calculation of overall atom economy **(1)**	<u>Example of calculation</u> 39.1 + 35.5 + 48 (= 122.6) 122.6 + (3 ×18) + ((71+40.1) × 3) = 509.9 Value for M2 should be consistent with numerator of atom economy expression (122.6 ÷509.9) ×100 = 24.044 = 24.0 % Ignore SF except 1 SF Use of 39 for K or 40 for Ca is acceptable Allow TE from (a)(i) using either M_r of all products or reactants Allow TE throughout calculation But TE for M3 must give a value of less than 100 %	3

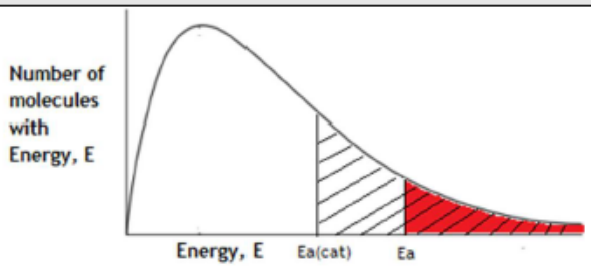
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • disproportionation reaction **(1)** • as chlorine (atoms) are oxidised from 0 (in chlorine) to (+) 5 (in calcium chlorate) **(1)** • and reduced (from 0) to −1 (in calcium chloride) **(1)**	Allow incorrect spellings of disproportionation if the word is recognisable and could not be confused with another chemical term Ignore redox Mark independently of M2 and M3 If initial oxidation state of 0 is not referenced at least once in either M2 or M3, then allow 1 for Cl is oxidised to +5 and reduced to -1 Changes in oxidation number can be shown above equation If no reference to oxidation and reduction then allow 1 mark for correct changes in oxidation number	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points: • add (dilute) nitric acid and silver nitrate (solution) **(1)** • white precipitate forms / precipitate forms whose colour is difficult to distinguish (between white and cream) **(1)** • which dissolves in dilute ammonia / dilute NH_3 / $NH_3(aq)$**(1)**	Throughout the question if formulae are given they must be correct Allow acidified silver nitrate / $AgNO_3$ and H^+ Allow $AgNO_3$ Allow HNO_3 Do not award hydrochloric acid / sulfuric acid Allow white solid / white crystals / white ppt Allow aqueous ammonia Allow 'disappears' for dissolves Do not award **just** 'dissolves in concentrated NH_3' M2 and M3 dependent on reference to silver nitrate / $AgNO_3$	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of mass of oxygen **(1)** • calculation of moles of oxygen **(1)** • deduction of moles of potassium chlorate /calculation of mass of KCl **(1)** • calculation of mass of potassium chlorate in impure sample **(1)** • calculation of % purity of sample to 2 or 3 SF **(1)**	<u>Example of calculation</u> 1.52 − 1.02 = 0.50 (g) 0.50 ÷ 32 = 0.015625 (mol) 0.015625 × (2÷3) = 0.010417 (mol) / 0.015625 x (2/3) x 74.6 = 0.777 (g) 0.010417 × (39.1 + 35.5 + 48) = 1.2771 (g) / 0.777 + 0.5 = 1.277 (g) = (1.2771 ÷ 1.52) × 100 = 84.019 = 84 / 84.0 (%) Penalise incorrect rounding once only in M1-M4 Allow TE at each step, but TE for M5 must give a value less than 100% and based on 1.52 Allow alternative methods based on finding x where x = mass of impurity	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	potassium chlorate(VII) OR chlorate(VII) potassium	Allow pottassium chlorate(VII) Do not award just potassium chlorate	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to any four of the following points: • heat to constant mass so all of the potassium chlorate(V) decomposes **(1)** • the solid product or potassium chloride dissolves (when the water is added) **(1)** • the rinsing removes potassium chloride (solution, which would otherwise add to the mass of the solid when it dries **(1)** • drying ensures the final mass recorded is only that of that catalyst **(1)** • the mass (of solid) recorded (at the end of the procedure) should be the same of that of the catalyst at the start **(1)**	Allow so all $KClO_3$ reacts / so reaction goes to completion Allow the catalyst does not dissolve (when the water is added) Ignore KCl reacts with the water / catalyst does not react with the water Allow to remove soluble impurities (from catalyst) Allow 'to remove water from the catalyst' / 'ensure the catalyst is dry' Allow 'to compare to the mass of catalyst' Allow 'to check the mass (of catalyst) hasn't changed'	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • activation energies shown and labelled for both catalysed and uncatalysed reaction **(1)** • number of molecules with $E > E_a$ shown on diagram **(1)**	 M2 can be awarded by written description	2

Q20.

Question Number	Answer	Additional Guidance	Mark
(a)(I)	• the arrow pointing to the C=C bond is incorrect **and** the arrow should be pointing away from the bond **(1)** • the partial charge on the C in the intermediate is incorrect **and** it should be a full positive charge **(1)**	Ignore references to lone pairs of electrons Either/both marks could be scored by annotations to the mechanism or using structures in the answer spaces	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(II)	• balanced equation • **(1)** • calculation of mass of chloroethene **and** total mass of reactants / products **(1)** • calculation of % atom economy **(1)**	$C_2H_4 + Cl_2 \rightarrow C_2H_3Cl + HCl$ Ignore state symbols (even if incorrect) Mass of chloroethene = 62.5 Total mass of reactants / products = 99 % Atom economy = $\frac{62.5}{99} \times 100$ = 63.131(%) = 63.1(%) TE on incorrect equation providing the product is chloroethene incorrect molecular masses no TE on incorrect atom economy expression If no other mark is scored correct expression for atom economy scores 1 Ignore SF except 1SF Correct answer with no working scores M3	**(3)**

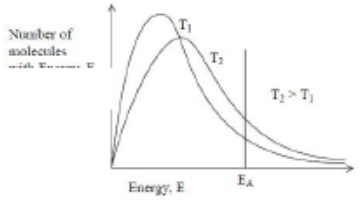
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • Atom economy (of process A is < 100% but) in process B it is 100% **(1)** • in process A HCl(g) is produced which is toxic / corrosive or catalyst for process B / Mercury / Mercury(II) chloride is highly toxic **(1)**	Allow no other product formed in process B Ignore just "process B has a higher atom economy than A" Accept reverse arguments e.g. A does not require a toxic catalyst M2 - Allow **both** processes use non-renewable starting material Do not award Ozone depletion Ignore references to energy involved in either process/ greenhouse gases / acid rain	**(2)**

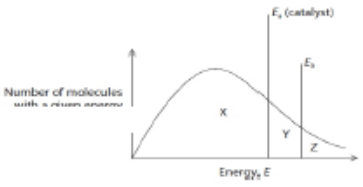
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (c)</td><td>This question assesses a candidate's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
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</table>
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table></td><td>The mark for indicative content should be added to the mark for lines of reasoning.
In general it would be expected that 5 or 6 indicative points would score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning.

Reasoning marks may be subtracted for extra incorrect chemistry.

If there is any incorrect Chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s).</td><td>(6)</td></tr>
</table>

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<tr><th>Question</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>Indicative content
The following table shows how the marks should be awarded for structure and lines of reasoning.
Indicative content
• axes labelled correctly
• shape of two curves at two different temperatures
• activation energy with and without a catalyst shown
• molecules with $E>E_a/E=E_a$ can react/ collisions are successful
• increasing temperature (increases energy of all molecules so) increases molecules / collisions with $E>E_a/E=E_a$ (so rate increases)
• adding a catalyst (provides an alternative pathway which) lowers E_a so more molecules / collisions have $E>E_a/E=E_a$</td><td>Vertical axis labelled fraction / proportion / percentage / number of molecules
Horizontal axis labelled E / energy

Both curves start at 0 and be asymptotic to the horizontal axis. The higher temperature curve must have a lower maximum and be moved to the right
Do not award asymptotes which are higher than 30% of their peak height
 



All the information may be shown on one axis grid and the two different temperatures can be implied unless incorrect.</td><td>(6)</td></tr>
</table>

Q21.

Question Number	Answer	Mark
(a)	**The only correct answer is A** (increase rate, decrease yield) *B is incorrect because an increase in temperature would increase the rate* *C is incorrect because the equilibrium would move to the left, i.e. endothermic direction* *D is incorrect because an increase in temperature would increase the rate and the equilibrium would move to the left, i.e. endothermic direction*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is C** (increase rate, increase yield) *A is incorrect because an increase in pressure would increase the yield* *B is incorrect because an increase in pressure would increase the rate and yield* *D is incorrect because an increase in pressure would increase the rate*	(1)

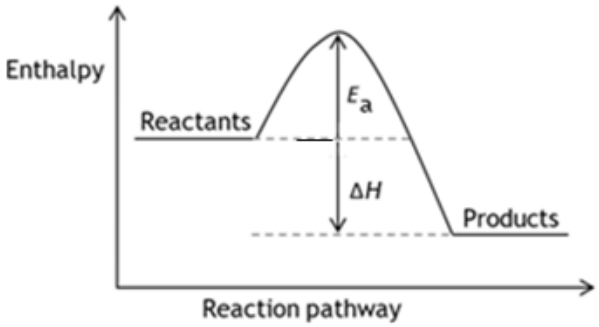
Q22.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (v) ***A** is incorrect because u is the activation energy for the reaction R→P* ***C** is incorrect because w is the activation energy for the reaction P→R* ***D** is incorrect because **x** is the enthalpy change for the reaction P→R*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is C** (w) ***A** is incorrect because u is the activation energy for the reaction R→P* ***B** is incorrect because v is the enthalpy change for the reaction R→P* ***D** is incorrect because **x** is the enthalpy change for the reaction P→R*	(1)

Question Number	Answer	Mark
(c)	**The only correct answer is C** (u −w = v) ***A** is incorrect because v+**x** =0 and u+w is the sum of the activation energies* ***B** is incorrect because w-**x** = u* ***D** is incorrect because u-v = w (not **x**)*	(1)

Q23.

Q	Answer	Mark
	 **The only correct answer is A** ( ) ***B*** *is incorrect because the labels are incorrect* ***C*** *is incorrect because the labels are incorrect and this is for an endothermic reaction* ***D*** *is incorrect because the labels are incorrect and is for an endothermic reaction*	**1**

Q24.

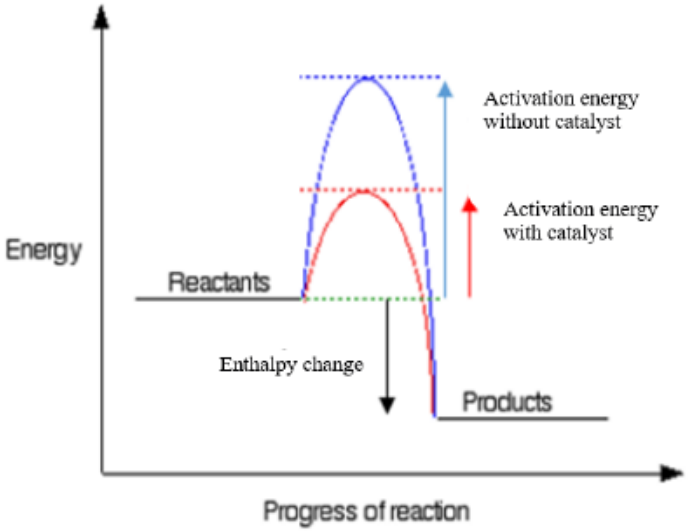
Question Number	Answer	Mark
	The only correct answer is B (decreasing the concentration of the hydrochloric acid) ***A*** *is incorrect because an increase in reactant concentration would reduce the time taken* ***C*** *is incorrect because raising the temperature would reduce the time taken* ***D*** *is incorrect because adding a catalyst would reduce the time taken*	**(1)**

Q25.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • **both** have London forces (only) **(1)** • S molecules have more electrons / S is a larger molecule (than oxygen) / S electrons are more easily polarised **(1)** Independent marks	Accept dispersion forces Accept instantaneous dipole-induced dipoles Allow van der Waals' forces Note any mention of other intermolecular forces being present e.g. dipole-dipole negates M1 Allow S_8, rather than O_2 Allow just S has more electrons Allow just S is larger Allow reverse argument Ignore electron density Do not award a S atom has more electrons than an oxygen molecule	

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: Increasing temperature **(1)** • equilibrium shifts to the LHS/backwards **(1)** • in the endothermic direction (in order to reduce the temperature) Increasing pressure **(1)** • equilibrium shifts to the RHS/forward **(1)** • to the side with fewer (gaseous) molecules/moles (in order to reduce the pressure) Independent marks	Ignore any reference to yield Allow reaction is exothermic Allow favours endothermic direction Allow favours RHS/forward direction Allow 3 moles (of gas) on the LHS (forms) 2 moles(of gas) on the RHS. If numbers of moles are quoted they must be correct. Allow reverse argument Ignore any reference to rate	**4**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: Increasing temperature • equilibrium shifts to the LHS/backwards (1) • in the endothermic direction (in order to reduce the temperature) (1) Increasing pressure • equilibrium shifts to the RHS/forward (1) • to the side with fewer (gaseous) molecules/moles (in order to reduce the pressure) (1) Independent marks	Ignore any reference to yield Allow reaction is exothermic Allow favours endothermic direction Allow favours RHS/forward direction Allow 3 moles (of gas) on the LHS (forms) 2 moles(of gas) on the RHS. If numbers of moles are quoted they must be correct. Allow reverse argument Ignore any reference to rate	4

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• reactants/(2)SO_2 + O_2 higher than products/(2)SO_3 (1) • non-catalysed activation energy correctly labelled and arrow going up (1) • catalysed activation energy correctly labelled and arrow going up (1) • enthalpy change labelled and arrow going down If just one curve is drawn max (3) MB distribution scores (0) If endothermic reaction TE available for M2. M3 and M4 Double-headed arrows or no arrow heads penalise once	 Allow energy for enthalpy Allow E_a and E_{cat} Allow intermediates in the activation energy curves Ignore sign and units of energy even if incorrect	4

Question Number	Answer	Additional Guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • (operates at) a lower temperature (1) • less energy required (for the reaction to proceed at an acceptable rate) or less burning of fossil fuels / less greenhouse gas evolved / less CO_2 evolved (1)	Allow lower temperature Allow less energy costs Ignore just cheaper Ignore less time/faster rate Allow less pollution	2

Question Number	Answer	Additional Guidance	Mark
* (b)	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout / 2 Answer is partially structured with some linkages and lines of reasoning / 1 Answer has no linkages between points and is unstructured / 0	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning	6

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	Indicative content <u>Potassium chloride</u> IP1 (misty/steamy fumes of) HCl/hydrogen chloride <u>Potassium iodide</u> IP2 purple vapour/black solid **and** I_2 /iodine IP3 bad eggs **and** H_2S/ hydrogen sulfide OR yellow solid **and** S/ sulfur OR Choking gas **and** SO_2/sulfur dioxide IP4 KCl is **not** a redox reaction and KI is a redox reaction / KCl cannot reduce sulfuric acid but KI can IP5 iodide stronger reducing agent than chloride IP6 (because) S is reduced from +6 to – 2 in H_2S OR S is reduced from +6 to 0 in S OR S is reduced from +6 to + 4 in SO_2 OR Any balanced equation making H_2S, SO_2, or S showing electrons eg $8H^+ + H_2SO_4 + 8e^- \longrightarrow H_2S + 4H_2O$ $2H^+ + H_2SO_4 + 2e^- \longrightarrow SO_2 + 2H_2O$ $6H^+ + H_2SO_4 + 6e^- \longrightarrow S + 4H_2O$	Note observation is not required for IP This can be seen in an equation Ignore any reference to hydrogen iodide/HI/misty fumes The two parts of this answer may often be seen in different places. Allow hydrogen iodide or potassium iodide is a stronger reducing agent than hydrogen chloride or potassium chloride. Allow reducing ability (of the halides) increases down the group Or reverse argument Do not award iodine/I is a stronger reducing agent than chlorine/Cl Allow just correct stated product and oxidation number eg – 2 in H_2S or 0 in S or + 4 in SO_2 Ignore I_2 oxidation number = 0	

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Question Number	Answer	Additional Guidance	Mark
(c)	• number of moles of sulfuric acid in 40.5 cm^3 (1) • concentration of the concentrated sulfuric acid (1)	Example of calculation $1.5 \times 500 \div 1000 = 0.75$ (mol) $0.75 \times 1000 \div 40.5 = 18.519$ (mol dm^{-3}) Allow TE on incorrect moles Units not required but if given they must be correct Correct answer with or without working scores (2) Ignore SF except 1 SF	2

Q26.

Question Number	Answer	Additional guidance	Mark
(a)	$CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$	Ignore state symbols even if incorrect Allow multiples Allow 2 correct equations via aldehyde Allow molecular formulae Ignore reagents above the arrow	(1)

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<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
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This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

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Guidance on how the mark scheme should be applied.

The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).
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If there is any incorrect chemistry, deduct mark(s) from the reasoning.
If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.
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	Indicative content 1. The higher the concentration (of acid or $Cr_2O_7^{2-}$) the higher the rate 2. Because the collision frequency increases 3. The higher the temperature the faster the rate 4. Because more particles have an energy greater than the activation energy / more successful collisions 5. Excess / concentrated oxidising agent ensures complete oxidation 6. Heat under reflux ensures complete oxidation	I2 can be scored independent of I1 must be linked to heating / higher temperature. Allow 'more effective collisions', Allow 'only propanoic acid is formed' / 'no propanal is formed' as alternative for 'complete oxidation' in I5 and I6 Ignore any reference to pressure	

Question Number	Answer	Additional guidance	Mark
(c)	• colour of the potassium dichromate(VI) / chromium(III) will mask the colour of the indicator or the reaction mixture will contain hydrogen ions / acid (present from the oxidising agent)	Ignore references to 'not a sharp colour change' Allow any named mineral acid	(1)

Question Number	Answer	Additional guidance	Mark
(d)(i)	An answer that makes reference to the following points • colourless **(1)** to • (pale) pink **(1)**	Colours in the reverse order scores one Do not award red / purple	(2)

Question Number	Answer	Additional guidance	Mark
(d)(ii)	An answer that makes reference to two of the following points: • First titre likely to be a rangefinder / rough titration / estimate (so done quickly) **(1)** • There was an air bubble (in the burette jet which fills before the titration starts) **(1)** • **Burette** rinsed with water (rather than sodium hydroxide) **(1)**	Allow 'not added dropwise' (near end point) / 'overshot at end point' Allow 'some water still in the burette after rinsing' **Ignore** pre-titration errors parallax errors water in conical flask **Do not award** lack of swirling of conical flask water in pipette	**(2)**

Question Number	Answer	Additional guidance	Mark
(d)(iii)	• calculation of average titre **(1)** • calculation of moles of NaOH(aq) in average titre and deduction of moles of propanoic acid in 25.0 cm^3 **(1)** • calculation of moles of propanoic acid in 250 cm^3 **(1)** • Evidence of correct *M*, **(1)** • calculation of mass of propanoic acid in the sample **(1)**	<u>Example of calculation</u> (22.20 + 22.10) / 2 = 22.15 cm^3 (22.15/1000) x 0.00668 = 1.47962 x 10^{-4} (mol) 1:1 reaction so = 1.47962 x 10^{-4} (mol) 1.47962 x 10^{-4} x 10 = 1.47962 x 10^{-3} (mol) 74 (g mol^{-1}) 1.47962 x 10^{-3} x 74 = 0.10949 (g) = 0.109 (g) / 0.11 (g) Correct answer with no working scores 5 Final answer to 2 or 3 SF Allow TE at each stage	**(5)**

Question Number	Answer	Additional guidance	Mark
(d)(iv)	calculation of mass of propanoic acid in mg **(1)** calculation of mass of propanoic acid in mg kg^{-1} and comparison to limit **(1)**	Example of calculation $0.109 \times 10^3 = 109$ (mg) Comment This mark may be evident in d(iii) $109 \times 20 = 2180$ (mg kg^{-1}) so within permitted range M1 is subsumed by M2 Allow TE from (d)(iii) Ignore SF except 1 SF	**(2)**

Question Number	Answer	Additional guidance	Mark
(d)(v)	An answer that makes reference to one of the following points: • (below the limit) the food would become mouldy (too quickly) / would not stop the food decomposing / would not be an effective preservative • (or above the limit) the food tastes bad / becomes (too) acidic / becomes inedible / becomes corrosive / becomes toxic	Ignore harmful	**(1)**