PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: EQUILIBRIA

SCORE	PERCENTAGE
/158	%

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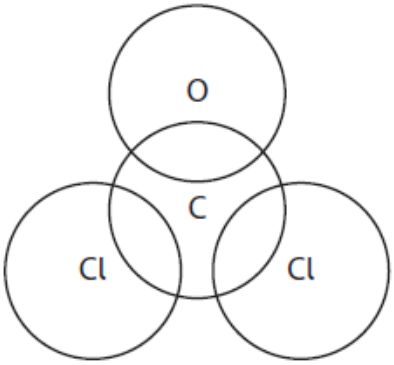
Q1.

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).

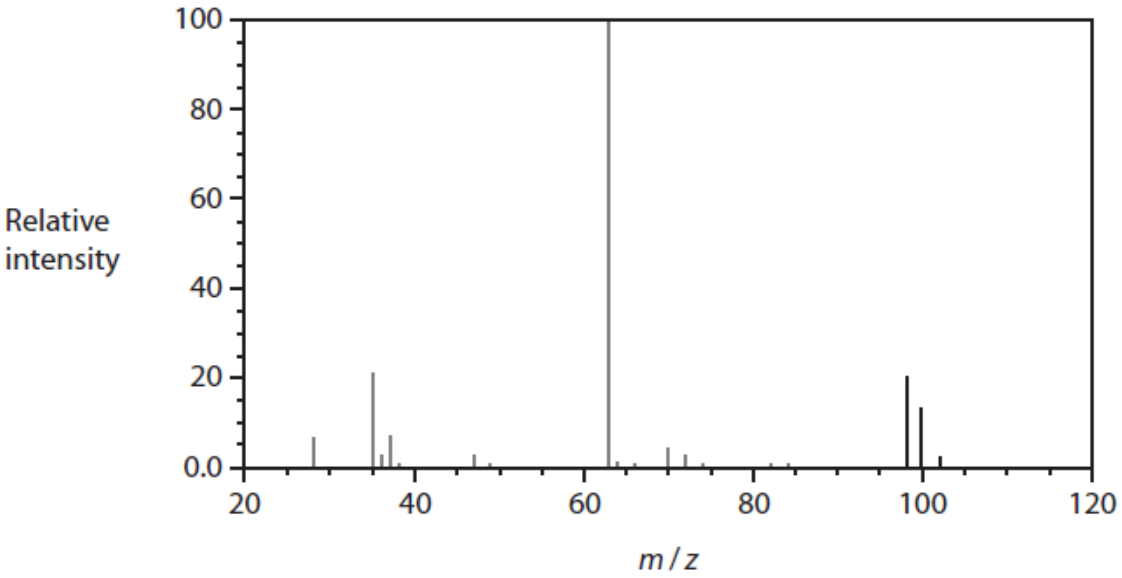
Include state symbols in your cycle.

(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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(Total for question = 20 marks)

Q2.

(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.

(2)

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

(3)

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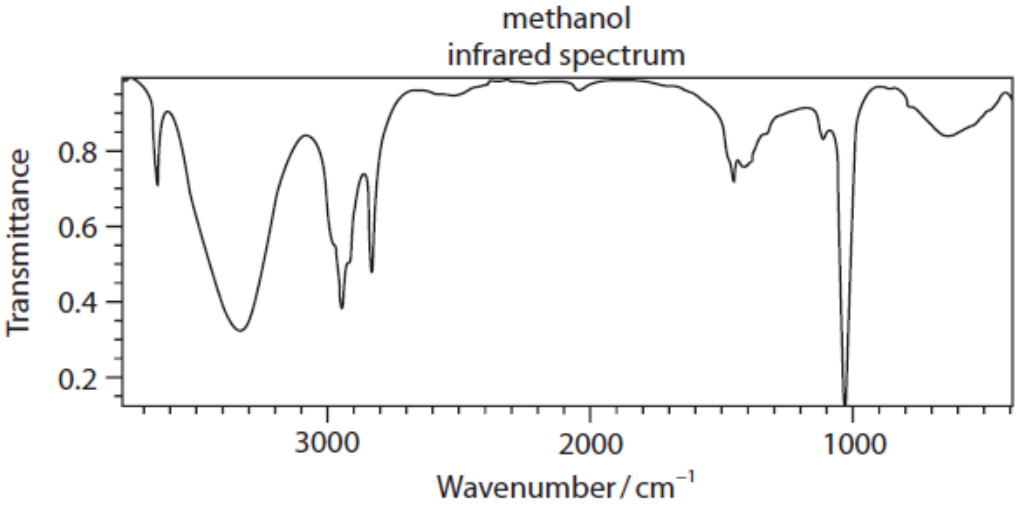
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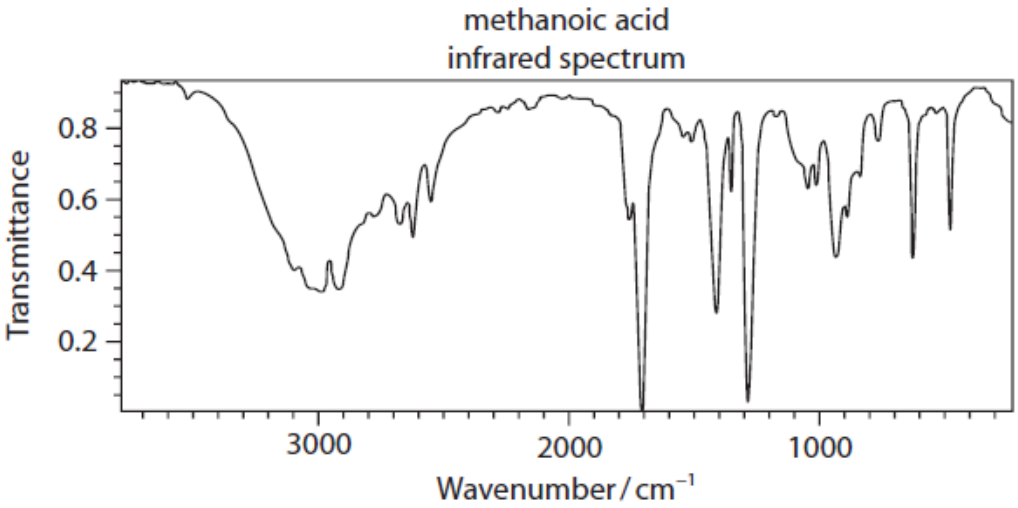
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(iv) The infrared spectra of methanol and methanoic acid are shown.

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.

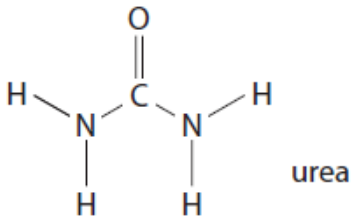
[Assume petrol has the same molecular formula as octane and the added methanol does not contribute any additional
carbon dioxide when burned.]

(2)

(Total for question = 19 marks)

Q3.

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.

(2)

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

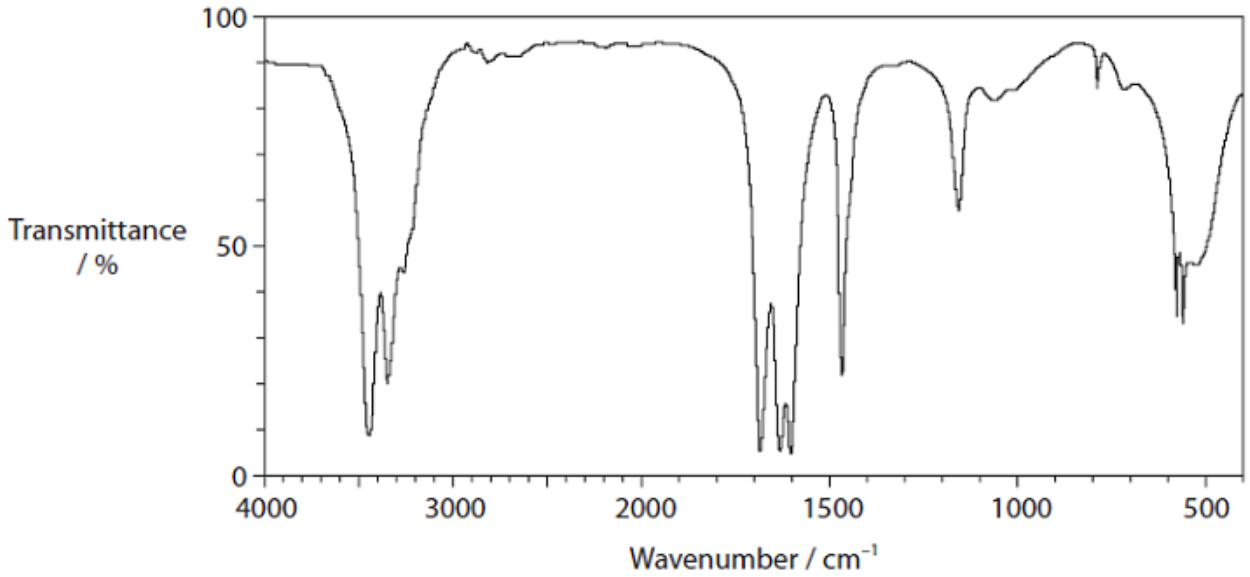
(1)

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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.

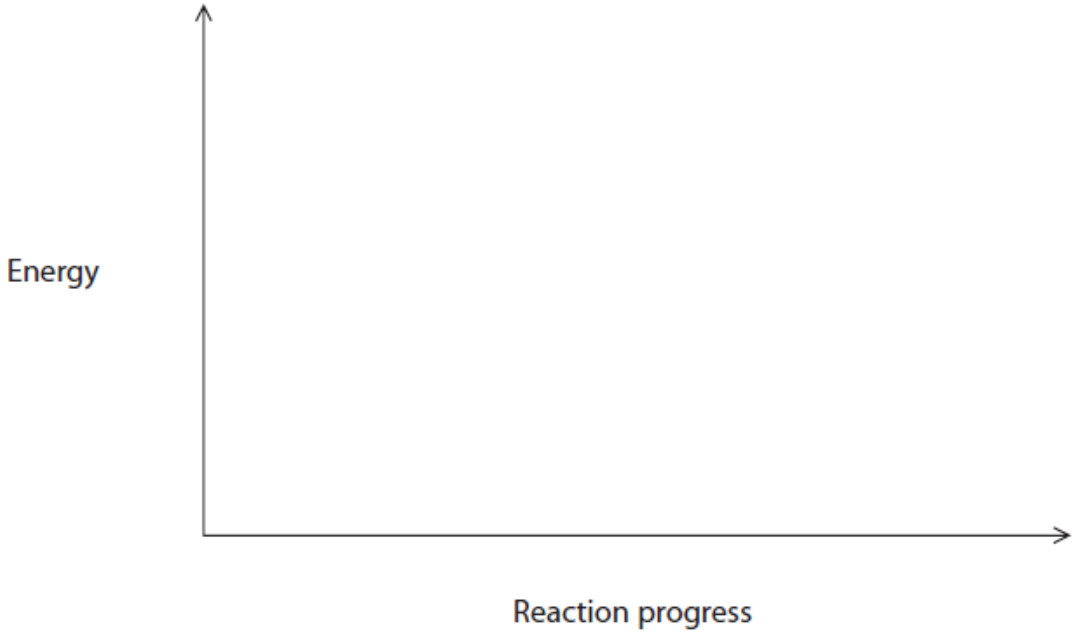
(1)

$(NH_2)_2CO + H_2O$

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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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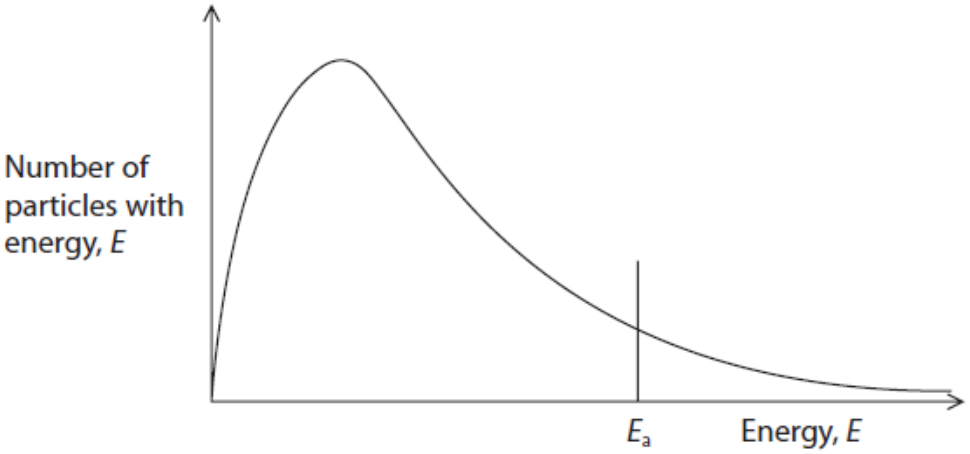
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(1)

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

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

(3)



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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.

(1)

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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)

Q4.

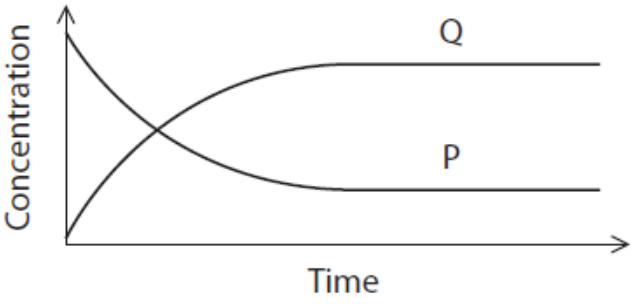
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A large amount of P is added to a small amount of Q. A reversible reaction occurs in which P reacts to form Q.

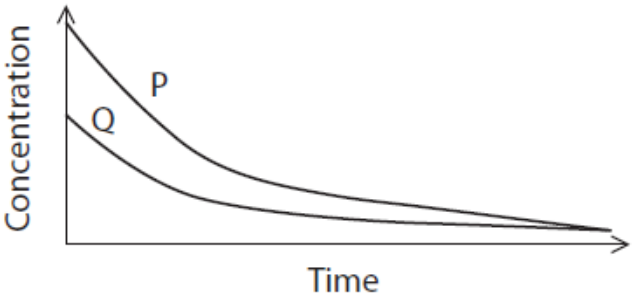
$$P \rightleftharpoons Q$$

Which graph shows how the concentrations of P and Q change as the reaction reaches equilibrium?

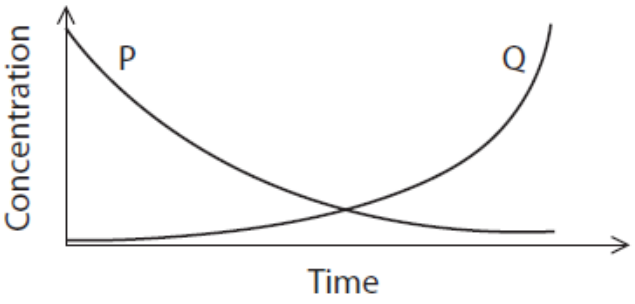
☒ **A**



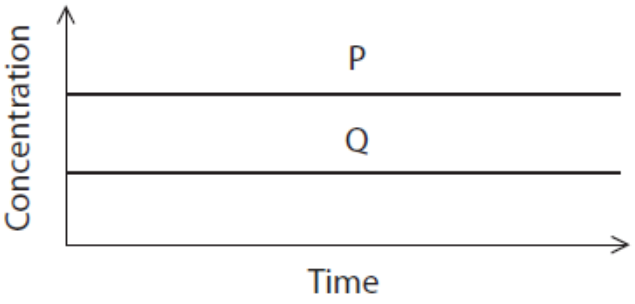
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q5.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which conditions give the highest yield for the forward reaction?

$$NH_4Cl(s) \leftrightarrow NH_3(g) + HCl(g) \qquad \Delta H = +176 \text{ kJ mol}^{-1}$$

☒ **A** high temperature, high pressure

☒ **B** high temperature, low pressure

☒ **C** low temperature, high pressure

☒ **D** low temperature, low pressure

(Total for question = 1 mark)

Q6.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Nitrogen dioxide and dinitrogen tetroxide exist in equilibrium.

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

When an equilibrium is set up in a gas syringe, the mixture is pale brown.

When the mixture is compressed the colour becomes

☒ **A** darker

☒ **B** lighter

☒ **C** darker and then lighter

☒ **D** lighter and then darker

(Total for question = 1 mark)

Q7.

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 ☒.

A mixture of hydrogen and iodine is left in a sealed container at 300°C until equilibrium is established.

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

The equilibrium mixture is then cooled and the colour of the mixture darkens.

Which is correct?

	Change in position of equilibrium when the system is cooled	Enthalpy change of forward reaction
☒ **A**	left	endothermic
☒ **B**	left	exothermic
☒ **C**	right	endothermic
☒ **D**	right	exothermic

(Total for question = 1 mark)

Q8.

The equilibrium reaction shown in the equation was studied by placing the components into a sealed glass container.

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

At equilibrium, which of the following statements is **not** true?

(1)

☒ **A** the concentrations of the $NO_2(g)$ and $N_2O_4(g)$ both remain constant

☒ **B** the total number of molecules is constant

☒ **C** the forward and reverse reactions have both stopped

☒ **D** the rate of the forward reaction is equal to the rate of the reverse reaction

(Total for question = 1 mark)

Q9.

Ethanol can be made in industry by the reaction of ethene with steam, using a phosphoric(V) acid catalyst.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \quad \Delta_rH = -45 \text{ kJ mol}^{-1}$$

The reaction is carried out at 300°C and 60 atm. An initial yield of 5 % is achieved when the ethene and steam first pass through the reactor.

*(a) Explain the chemical reasons for the conditions used and why such a low initial yield is acceptable in the industrial process.

(6)

(b) The product of the reaction is a mixture of ethanol and water.

Explain why ethanol and water mix together fully.

You may find it helpful to draw a diagram.

(3)

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(c) Ethanol can be oxidised using a solution of acidified potassium dichromate(VI), $K_2Cr_2O_7(aq)$.

Ethanoic acid and another organic compound, **Y**, are both possible products.

(i) Draw the structure of **Y**.

(1)

(ii) State the conditions needed to maximise the yield of each product.

(2)

Conditions for maximum yield of **Y**

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Conditions for maximum yield of ethanoic acid

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(Total for question = 12 marks)

Q10.

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.

(1)

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

(1)

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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.

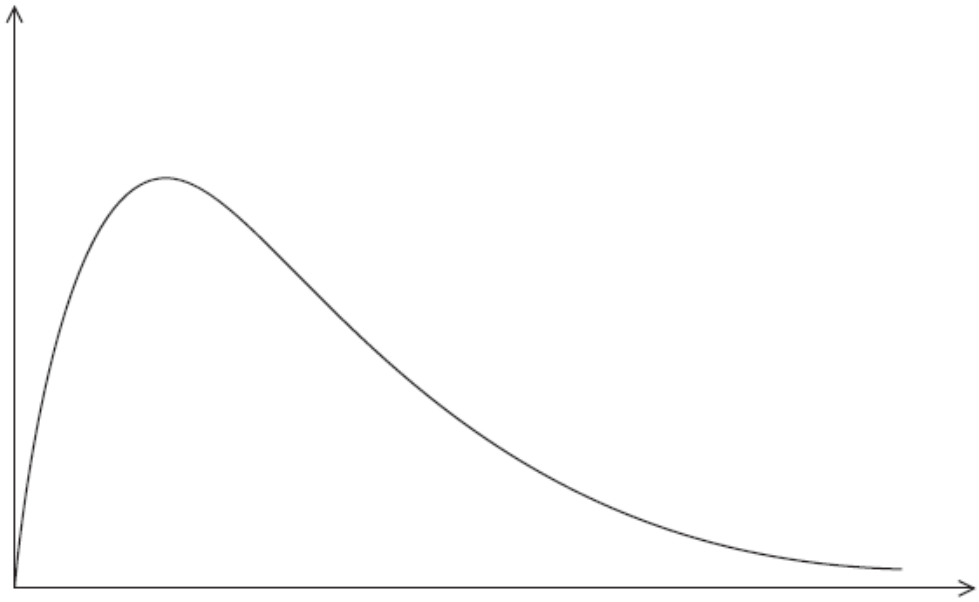
(6)

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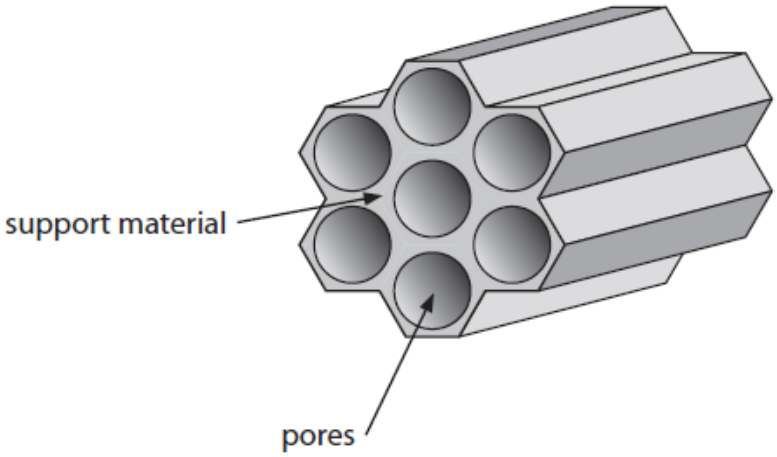
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(f) Catalysts such as phosphoric acid are bonded to a support material that contains lots of pores.



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

(1)

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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.

(2)

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(Total for question = 19 marks)

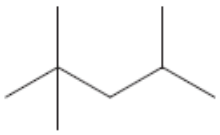
Q11.

Fuels

Fuels burn in oxygen to release a lot of energy.

Many hydrocarbons and alcohols are used as fuels. During complete combustion, they produce carbon dioxide and water.

Petrol contains 2,2,4-trimethylpentane, an isomer of octane, that promotes smooth combustion.



2,2,4-trimethylpentane

Alcohols, such as methanol and ethanol, can be used as fuels either on their own or as additives in petrol.

(a) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of 2,2,4-trimethylpentane is −5461 kJ mol^{-1}.

(i) State the two standard conditions for this enthalpy change.

(1)

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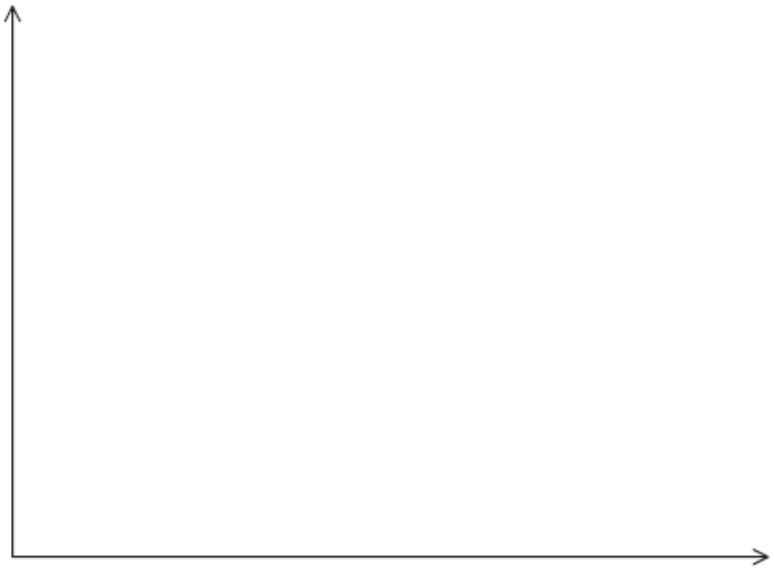
(ii) Write the equation for the complete combustion of 2,2,4-trimethylpentane, using **molecular** formulae.

State symbols are not required.

(2)

(iii) Draw a labelled enthalpy level diagram for the complete combustion of 2,2,4-trimethylpentane.

(2)

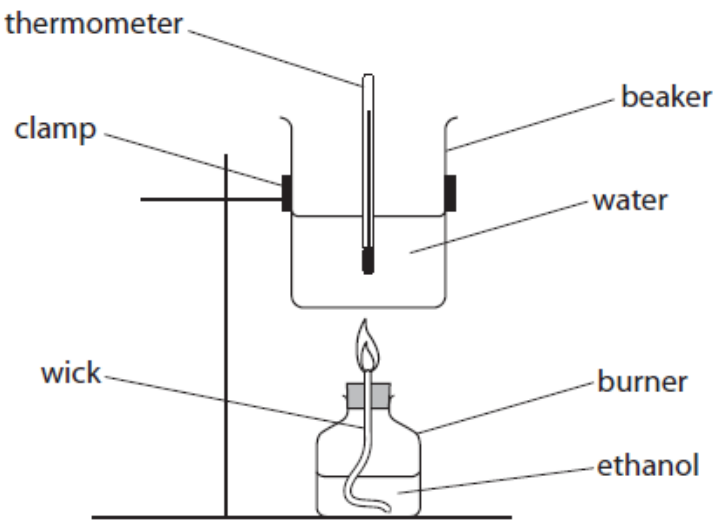


(iv) Calculate the heat energy released during the complete combustion of 1 dm^3 of 2,2,4-trimethylpentane.

[Density of 2,2,4-trimethylpentane = 0.692 g cm^{-3}]

(3)

(b) In an experiment to determine the enthalpy change of combustion of ethanol, C_2H_5OH, a student used the apparatus shown.



Results:

Mass of water = 100.0 g

Mass of ethanol used = 0.305 g

Temperature rise of water = 13.2°C

(i) Calculate the enthalpy change of combustion of ethanol.

Give your answer to an appropriate number of significant figures, and include a sign and units.

[Specific heat capacity of water = 4.18 J $g^{-1}°C^{-1}$]

(4)

(ii) The uncertainty in each thermometer reading is ±0.05 °C.

Calculate the percentage uncertainty in the temperature rise in this experiment.

(1)

(iii) The student looked in a data book and found the actual value for the standard enthalpy change of combustion of ethanol was more exothermic than the experimental value obtained.

Give **two** reasons for the difference between the data book value and the experimental value, other than referring to standard conditions.

(2)

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(c) The enthalpy changes for the conversion of four compounds in the gas phase into their constituent atoms are shown.

$$H_2O(g) \rightarrow 2H(g) + O(g) \qquad \Delta_r H = +928\,kJ\,mol^{-1}$$

$$CH_4(g) \rightarrow C(g) + 4H(g) \qquad \Delta_r H = +1740\,kJ\,mol^{-1}$$

$$CH_3OH(g) \rightarrow C(g) + 4H(g) + O(g) \qquad \Delta_r H = +2105\,kJ\,mol^{-1}$$

$$C_2H_5OH(g) \rightarrow 2C(g) + 6H(g) + O(g) \qquad \Delta_r H = +3322\,kJ\,mol^{-1}$$

Calculate the bond enthalpy of the C—C bond, in kJ mol^{-1}.
You **must** show your working.

(3)

(d) Ethanol can be manufactured by reacting ethene with steam.

$$C_2H_4(g) + H_2O(g) \leftrightarrow C_2H_5OH(g) \qquad \Delta_r H = -45 \text{ kJ mol}^{-1}$$

This reaction is usually carried out in industry at 300 °C and 70 atm pressure using a catalyst.

Explain the effect on the equilibrium position and the equilibrium yield of ethanol if the reaction is carried out at 300°C and 200 atm pressure.

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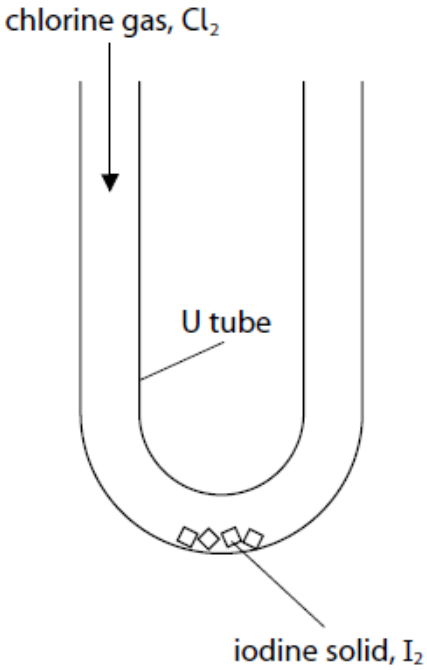
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(Total for question = 20 marks)

Q12.

Iodine monochloride, ICl, is a covalent compound produced by the reaction of iodine with chlorine. Iodine monochloride is a dark brown liquid at room temperature.

The equipment shown can be used to pass chlorine over solid iodine to produce iodine monochloride.



When excess chlorine is passed through the U tube, the iodine monochloride reacts to produce iodine trichloride in an equilibrium reaction.

(a) Write a chemical equation for the reaction of iodine with chlorine to produce iodine monochloride. Include state symbols.

(2)

(b) The iodine monochloride molecule has a permanent dipole. Complete the following table using the electronegativity data from your Data Booklet and hence show the dipole on the diagram of the iodine monochloride molecule.

(1)

Element	Electronegativity
Cl	
I	

I — Cl

(c) Iodine monochloride reacts with propene to form two isomeric products. This is an addition reaction that is similar to the reaction of propene with hydrogen halides.

(i) Draw the skeletal formulae of both isomers.

(2)

(ii) Explain which of these isomers is the major product.

(3)

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(d) The equation for the reaction between iodine monochloride and chlorine is:

$$\underset{\text{brown liquid}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow solid}}{ICl_3(s)}$$

(i) State and justify **one** precaution that must be taken when preparing iodine trichloride.

(2)

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(ii) Give the oxidation number of iodine in both iodine-containing compounds in the equilibrium.

(1)

I in ICl

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I in ICl_3

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(iii) Iodine trichloride can also be made by reacting potassium chlorate(V) with iodine in hydrochloric acid. The equation for the reaction is

$$KClO_3 + I_2 + 6HCl \rightarrow KCl + 2ICl_3 + 3H_2O$$

By considering oxidation numbers for chlorine, explain whether or not this reaction is a disproportionation.

(2)

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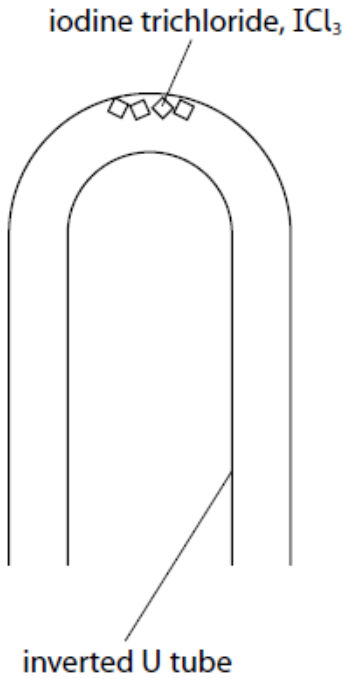
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(e) Chlorine gas has a molar volume of 24 000 cm^3 mol^{-1} under the conditions used in this reaction.

(i) Show that the density of chlorine gas is approximately 3 g dm^{-3}.

(2)

(ii) Air has an average density of 1.25 g dm^{-3}. If the U-tube used in part (d) is inverted, as shown in the diagram, the solid yellow iodine trichloride produced in the equilibrium reaction turns to a brown liquid.



Explain this observation.

(3)

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(f) A mass of 0.64 g of iodine reacted with fluorine to form 1.31 g of a fluoride of iodine.

Calculate the empirical formula of this compound of iodine and fluorine.

(2)

(Total for question = 20 marks)

Q13.

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)

Q14.

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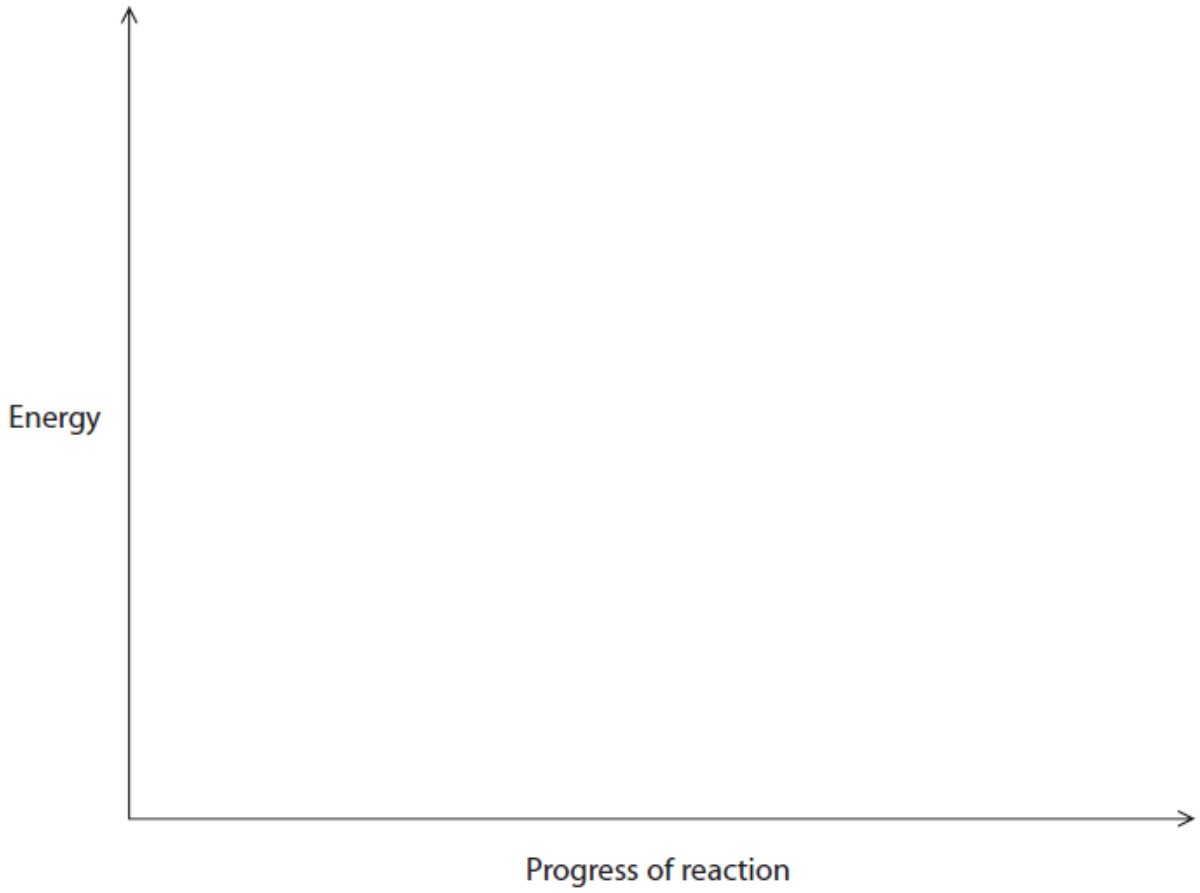
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(iii) Vanadium(V) oxide, V_2O_5, is used to catalyse the reaction in Step **2**.

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)

Q15.

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 equilibrium shifts to the right-hand side when the pressure in the system **decreases** at constant temperature?

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

☒ **B** $F_2(g) + H_2(g) \rightleftharpoons 2HF(g)$

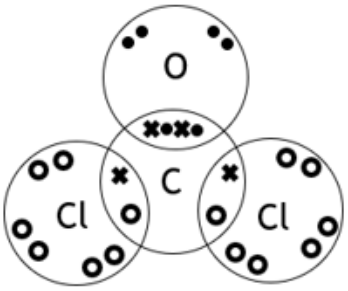
☒ **C** $C_6H_6(g) + 3H_2(g) \rightleftharpoons C_6H_{12}(g)$

☒ **D** $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$

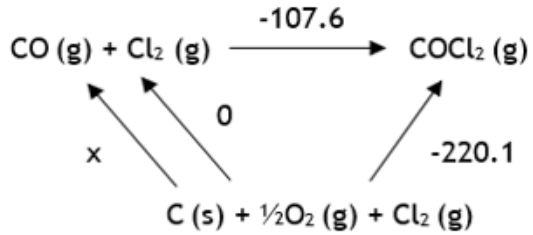
(Total for question = 1 mark)

Mark Scheme

Q1.

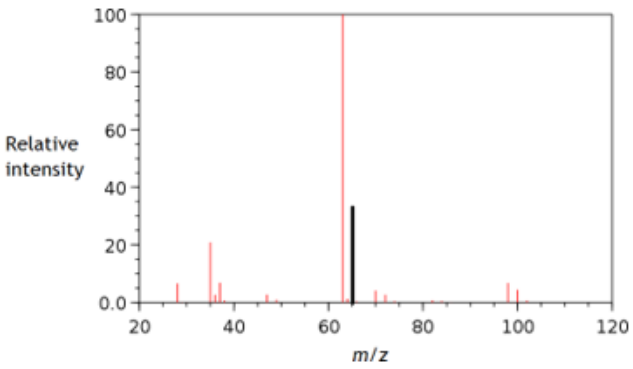
Q	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: A diagram that includes: • carbon singly covalently bonded to two chlorine atoms and three lone pairs on each chlorine **(1)** • carbon doubly bonded to an oxygen atom and two lone pairs on the oxygen **(1)**	 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	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)**

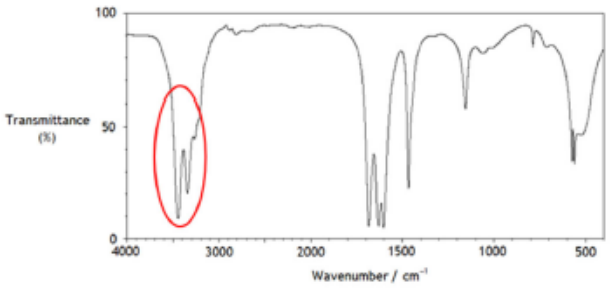
Question Number	Answer	Additional Guidance	Mark
(c)(iii)	• Mass petrol reduction per year **(1)** • Mass CO_2 reduction **(1)** OR • Moles of petrol used per year **(1)** • 5% reduction in CO_2 **(1)** OR • 5% reduction in moles of petrol used per year **(1)** • Mass CO_2 produced **(1)**	Example of 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)**

Q3.

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)**

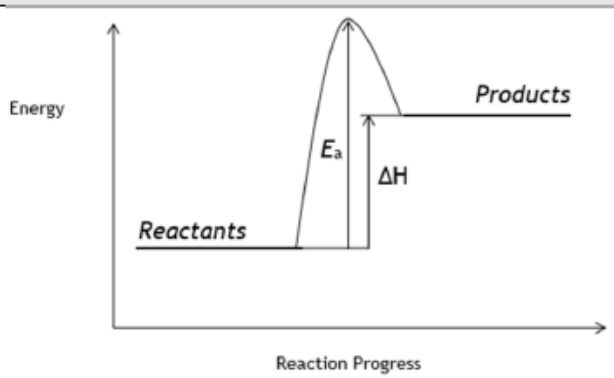
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • M_r of urea **(1)** OR moles of urea • mass of urea required **(1)**	M_r = 60 (9.07 ÷ 1000) × 150 = 1.36(05) (9.07 ÷ 1000) × 150 × 60 = 81.63 (g) / 81.6 (g) Ignore SF except 1 SF Correct answer 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)**

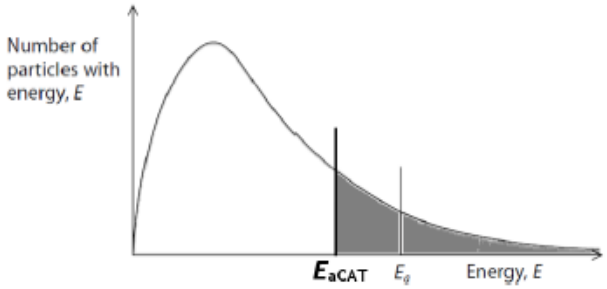
Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following point • C=O		**(1)**

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)**

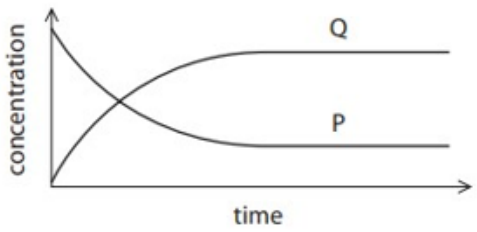
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Question Number	Answer	Additional Guidance	Mark
(f)(ii)	An explanation that makes reference to the following points: • catalyst decreases the activation energy required **(1)** • more particles have the energy required for the reaction to take place **(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)**	<u>An example of a calculation:</u> $89.3 \times 1000 = 89300\ dm^3$ $89300 \div 51.1 = 1747.6 / 1748$ mol $1748 \times 6.02 \times 10^{23} = 1.052 \times 10^{27} / 1.05 \times 10^{27} / 1.1 \times 10^{27}$ Allow TE throughout Ignore SF except 1SF Ignore units even if incorrect $1.052 \times 10^{24} / 1.05 \times 10^{24} / 1.1 \times 10^{24}$ scores 2 $1.052 \times 10^{21} / 1.05 \times 10^{21} / 1.1 \times 10^{21}$ scores 2 $2.747 \times 10^{30} / 2.75 \times 10^{30} / 2.8 \times 10^{30}$ scores 2 Correct answer with some working scores (3)	**(3)**

Q4.

Question number	Answer	Mark
	The only correct answer is A  ***B*** *is not correct because it shows the concentration of both reactants and products decreasing* ***C*** *is not correct because both concentration of reactants and products are still changing* ***D*** *is not correct because concentrations of P and Q remain unchanged*	**(1)**

Q5.

Question Number	Answer	Mark
	The only correct answer is B (high temperature, low pressure) ***A*** *is incorrect because high pressure would favour the back reaction* ***C*** *is incorrect because both these conditions would favour the back reaction* ***D*** *is incorrect because low temperature would favour the back reaction*	**(1)**

Q6.

Question Number	Answer	Mark
	The only correct answer is C (darker and then lighter) ***A*** *is incorrect because when the equilibrium is re-established the mixture becomes lighter* ***B*** *is incorrect because when the mixture is compressed it initially becomes darker* ***D*** *is incorrect because the colour change is reversed*	**(1)**

Q7.

Question number	Answer	Mark
	The only correct answer is A (change in equilibrium position: left, enthalpy change: endothermic) ***B*** *is incorrect because an exothermic reaction would decrease the concentration of iodine* ***C*** *is incorrect because the equilibrium position would shift to the left* ***D*** *is incorrect because the equilibrium position would shift to the left*	**(1)**

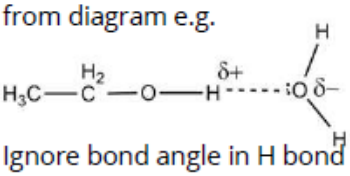
Q8.

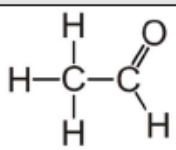
Question number	Answer	Mark
	C the forward and reverse reactions have both stopped	1

Q9.

Q	Acceptable Answers	Additional Guidance	Mark
(a)	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 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 Indicative Points	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 four 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 and overall score of 3 marks (3 marks for indicative content and zero marks for linkages). Note – allow reverse arguments where appropriate e.g. IP1 and IP5	6

• **IP1** High temperature increases rate as more particles have $E \geq E_a$ • **IP2** Catalyst increases rate by providing alternative mechanism / catalysts lower activation energy • **IP3** but high temperature reduces yield / moves eqm to LHS as reaction is exothermic • **IP4** so (high) temperature (of 300°) is a compromise (between rate and yield) • **IP5** high pressure increases the yield as reaction / equilibrium moves to side of fewest particles / high pressure increases rate as more particles in the same volume • **IP6** (low yield acceptable) as unconverted reactants can be recycled / passed through reactor again	May be shown on a labelled diagram Allow compromise between temperature or pressure and energy costs / equipment to withstand pressure/ costs to maintain temperature / costs to maintain pressure Allow (low yield acceptable) as ethanol is removed as it forms to move equilibrium to RHS Ignore any references to environmental effects / atom economy	

Q	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • when they mix can form hydrogen bonds (to each other) **(1)** • as both compounds have hydrogen bonds (between their molecules) OR forces that form are similar in strength or stronger than hydrogen bonds in water / ethanol **(1)** • from the lone pair / slight negative charge on an oxygen (atom in one molecule) to a slightly positive hydrogen (atom in the other molecule) (on OH group or water) **(1)**	Ignore references to other intermolecular forces Allow ethanol-water forces can overcome ethanol-ethanol / water-water forces M1 and M3 can be awarded from diagram e.g.  Ignore bond angle in H bond diagram Ignore hydrocarbon structure on ethanol	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)		Allow  Allow CH_3CHO Allow 'hybrid' structure e.g. skeletal but with some parts of the structure displayed Ignore bond angles Ignore correct molecular formulae Ignore attempts to write a balanced equation Ignore names even if incorrect Note Look out for structures drawn above the stem If 2 structures shown, e.g. skeletal and displayed, but one is incorrect then award 0 marks	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • Y - Distil (off Y from reaction mixture as it forms) **(1)** • Ethanoic acid – (heat under) reflux **(1)**	Note if both answers given but the wrong way round allow 1 mark If no other mark is awarded, controlling the amount of oxidising agent in either case scores (1) Ignore temperatures if given	2

Q10.

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)

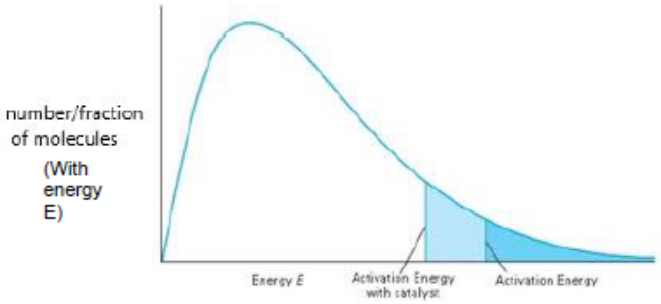
Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to one of the following points: • (water can cause) corrosion / rusting • reduce the energy efficiency of the engine/fuel/ethanol • causes phase separation of the fuel	Ignore damages the engine Allow water does not 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		

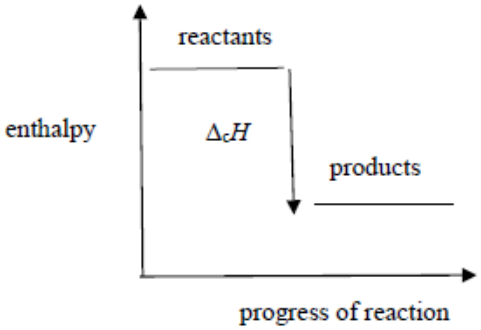
Question Number	Answer	Additional Guidance	Mark
(f)(i)	• large(r) surface area (so faster rate of reaction)	Accept more (active) sites Allow more / greater surface Ignore greater area / area of contact	(1)

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)

Q11.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• (temperature) 298 K / 25°C **and** (pressure) 1 atm / 100 kPa / 101 kPa / 1 x 10^5 Pa / 1.01 x 10^5 Pa	Allow 'a specified / stated temperature' Ignore just 'room temperature' Do not award 298°K Do not award incorrect pressure units e.g. 101 Pa	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• molecular formula for 2,2,4-trimethylpentane (1) • rest of equation correct **conditional** on use of C_8H_{18} **or** use of structural / displayed / skeletal formula for 2,2,4-trimethylpentane (1)	Example of equation: $C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$ Accept 25/2 for 12½ Allow multiples e.g. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ Ignore state symbols even if incorrect	(2)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• y axis labelled enthalpy **and** products line drawn at a lower level than reactants line (1) • downwards arrow labelled with $\Delta_c H$ (1)	Example of diagram;  Allow energy / H / enthalpy level as label for y axis Do not award ΔH / enthalpy change / energy change as label for y axis Allow names / formulae of reactants and products but both must be there e.g. $C_8H_{18} + O_2$ for reactants and $CO_2 + H_2O$ for products Ignore missing / incorrect balancing numbers if formulae given Ignore label / missing label on x axis Ignore activation energy hump(s) M2 Conditional on reactants higher than products Allow label as ΔH / −5461 / other label that indicates enthalpy change of combustion / reaction Do not award double headed arrow / or just a line with no arrow / arrow labelled $-\Delta H$	(2)

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Question Number	Answer	Additional Guidance	Mark
(a)(iv)	• calculation of energy given out by 1 g **(1)** • calculation of energy given out by 1 cm^3 **(1)** • calculation of energy given out by 1 dm^3 **(1)**	Example of calculation: **Method 1** enthalpy change / g = $\frac{5461}{114}$ = 47.904 (kJ) enthalpy change / cm^3 = 47.904 x 0.692 = 33.149 (kJ) TE on M1 enthalpy change / dm^3 = 33.149 x 1000 = 33 149 / 33.149 x 10^3 (kJ) TE on M2 **Method 2** mass of 2,2,4-trimethylpentane in 1 dm^3 = 0.692 x 1000 = 692 (g) (1) mol in 1 dm^3 = $\frac{692}{114}$ = 6.0702 (mol) (1) TE on M1 enthalpy change / dm^3 = 6.0702 x 5461 = 33 149 / 33.149 x 10^3 (kJ) (1) TE on M2 Allow alternative methods Correct answer with some working scores (3) Ignore SF except 1 SF Ignore minus sign Ignore units, even if incorrect	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of heat evolved (1) • calculation of moles of ethanol used (1) • working for heat evolved per mole (1) • value of $\Delta_c H$ to 2 / 3 SF **and** negative sign **and** units (1)	Example of calculation: heat evolved = 100.0 x 4.18 x 13.2 = 5517.6 (J) / 5.5176 kJ Do not award 100.305 x 4.18 x 13.2 = 5534.4 (J) amount of ethanol = $\frac{0.305}{46}$ = 0.0066304 / 6.6304×10^{-3} (mol) heat evolved per mole = $\frac{5.5176}{6.6304 \times 10^{-3}}$ (= 832.17) TE on M1 and M2 $\Delta_c H$ = − 830 / − 832 kJ mol^{-1} Allow units kJ/mol or $\frac{kJ}{mol}$ or kJ mol^{-} Ignore letter case in units e.g. k or K, J or j Accept − 830 000 / − 832 000 J mol^{-1} TE on M3 Ignore SF except 1 SF in M1, M2 and M3 Correct answer with some working to 2/3 SF with sign and units scores (4)	(4)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation of percentage error	Example of calculation: $\frac{2 \times 0.05}{13.2} \times 100) = 0.75758$ (%) Allow 0.7576 / 0.758 / 0.76 / 0.8 Correct answer with no working scores (1) Ignore signs Do not award 0.75 / 0.757 / 0.80	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to any **two** of the following points: • heat loss (to the surroundings) (1) • incomplete combustion (of ethanol) (1) • some ethanol evaporates (1) • calculation does not take into account the heat capacity of the beaker (1)	Allow insufficient oxygen for combustion Ignore not all of the ethanol was burned Ignore product(s) / water evaporates Allow some heat is used to heat up the beaker Ignore thermometer Ignore ethanol was impure Ignore water was not stirred Ignore no lid on beaker	(2)

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Question Number	Answer	Additional Guidance	Mark
(c)	• calculation of bond energies of O–H **and** C–H (1) • calculation of bond energy of C–O (1) • calculation of bond energy of C–C (1)	Example of calculation: **Method 1** bond energy O–H = 928/2 = (+)464 (kJ mol^{-1}) **and** bond energy C–H = 1740/4 = (+)435 (kJ mol^{-1}) bond energy C–O = 2105 – (3 x 435) – 464 = (+)336 (kJ mol^{-1}) TE on M1 bond energy C–C = 3322 – (5 x 435) – 464 –336 = (+)347 (kJ mol^{-1}) **Method 2** 3322 – 2105 = 1217 = C–C + 2 x C–H (1) bond energy 2 x C–H = 1740/2 = (+)870 (kJ mol^{-1}) (1) C–C = 1217 – 870 = (+)347 (kJ mol^{-1}) (1) M3 TE on M1 and M2 in both methods Correct answer with some working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
(d)	An answer that makes reference to the following points: • there are fewer (gas) molecules on the right hand side / more (gas) molecules on the left hand side (1) • so the equilibrium position will shift to the right / product side **and** the equilibrium yield of ethanol will increase (1)	Ignore effect of temperature Ignore effect on rate of reaction Allow moles for molecules Allow 2 (gas) molecules on the left and 1 (gas) molecule on the right Allow higher pressure favours the side with fewer (gas) molecules Allow forward reaction is favoured **and** the equilibrium yield of ethanol will increase	(2)

Q12.

Question number	Answer	Additional guidance	Mark
(a)	• balanced equation (1) • all states correct (1)	$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$ Accept multiples	2

Question number	Answer	Additional guidance	Mark
(b)	• correct electronegativity values and correct dipole diagram	Cl = 3.0 **and** I = 2.5 δ+ I — Cl δ- Do not award full charges	1

Question number	Answer	Additional guidance	Mark
(c)(i)	• 1 mark each correct formula	 Allow 1 mark for 2 correct non-skeletal formulae	2

Question number	Answer		Additional guidance	Mark
(c)(ii)	An explantion that makes reference to the following points:			3
	• identification of correct isomer	(1)	2-chloro-1-iodopropane	
	• iodine is δ+ and is attacked by the π electrons	(1)		
	• more stable secondary carbocation formed.	(1)		

Question number	Answer		Additional guidance	Mark
(d)(i)	An answer that makes reference to the following points:			2
	• carry out in fume cupboard	(1)	Allow fume hood or similar description	
	• chlorine is toxic.	(1)	Do not allow 'harmful'	

Question number	Answer	Additional guidance	Mark
(d)(ii)	• I in ICl = +1 I in ICl_3 = +3	Both needed for the mark	1

Question number	Answer		Additional guidance	Mark
(d)(iii)	• +5 **and** -1 to -1 (and -1)	(1)		2
	• not disproportionation because the chlorine has not undergone both oxidation and reduction	(1)		

Question number	Answer		Additional guidance	Mark
(e)(i)	• correct method	(1)	$Cl_2 = 2 \times 35.5 = 71$ 71 ÷ 24000	2
	• answer with units	(1)	= 0.0029583 g cm^{-3} = 3 g dm^{-3}	

Question number	Answer	Additional guidance	Mark
(e)(ii)	An explanation that makes reference to the following points: • chlorine (gas) is more dense than air (1) • chlorine (gas) removed (from the equilibrium) (1) • position of equilibrium moves to the LHS (more brown liquid/ICl). (1)		3

Question number	Answer	Additional guidance	Mark
(f)	• calculation of mols of iodine and fluorine (1) • calculation of whole number ratio and formula (1)	Mols of iodine = $0.64 \div 126.9 = 5.04 \times 10^{-3}$ Mols of fluorine = $(1.31–0.64) \div 19 = 3.53 \times 10^{-2}$ Ratio 1:7 therefore formula IF_7	2

Q13.

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)

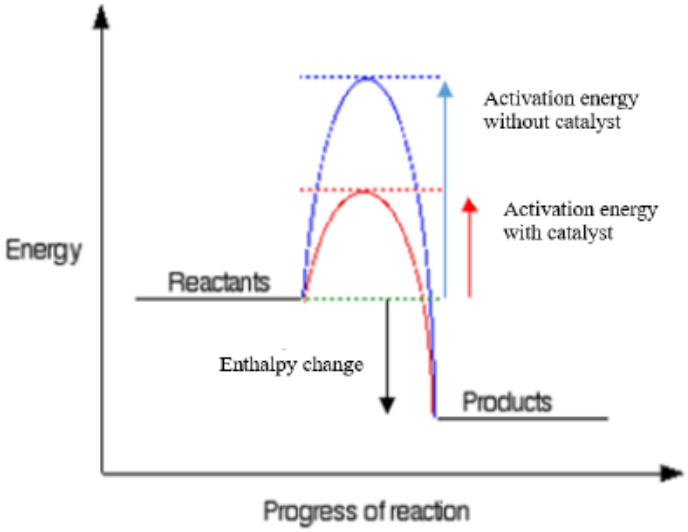
Question Number	Answer	Mark
(b)	**The only correct answer is C** (increase rate, increase yield) *A is incorrect because an increase in pressure would increase the yield* *B is incorrect because an increase in pressure would increase the rate and yield* *D is incorrect because an increase in pressure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

Q14.

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

Q15.

Question number	Answer	Mark
	The only correct answer is D ($2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$) *A is not correct because the equilibrium will move to the left hand side (more molecules)* *B is not correct because the equilibrium will not change as both sides have the same number of molecules* *C is not correct because the equilibrium will move to the left hand side (more molecules)*	**(1)**