Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Time 1 hour 30 minutes

Paper reference **8CH0/02**

Chemistry

Advanced Subsidiary
PAPER 2: Core Organic and Physical Chemistry

Candidates must have: Scientific calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need*.

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.
- Good luck with your examination.

Turn over ▶

Pearson

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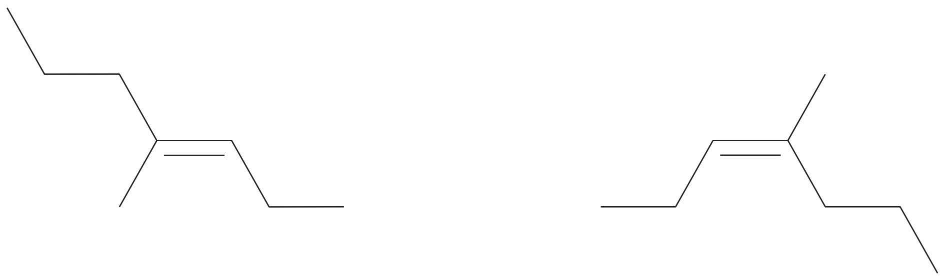
Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The structures of two isomers are shown.



What kind of isomerism is shown by these molecules?

☐ **A** carbon chain

☐ **B** positional

☐ **C** *E*/*Z*

☐ **D** *cis*/*trans*

(Total for Question 1 = 1 mark)

2 Phosphorus(V) chloride, PCl_5, can be thermally decomposed to phosphorus(III) chloride, PCl_3, and chlorine, Cl_2. The equation for this reaction is

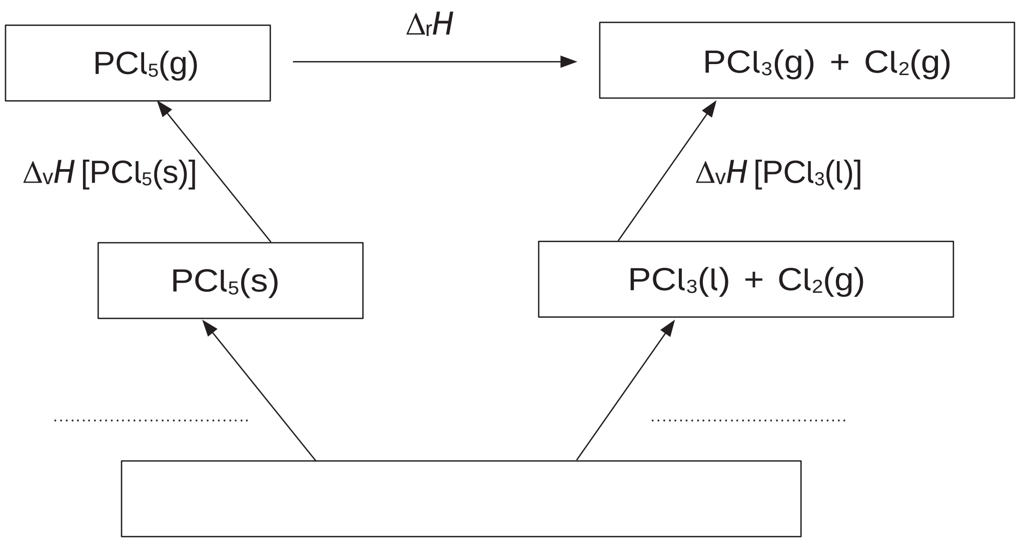
$$PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$$

The enthalpy change for this reaction cannot be measured directly.

(a) (i) Complete the Hess's Law cycle to include the enthalpy change of formation of both phosphorus chlorides.

Include the labels of the missing enthalpy changes.

$\Delta_v H$ is the enthalpy change for the vaporisation of the substance from the state shown to the gaseous state. **(3)**



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(ii) Calculate the enthalpy change for the thermal decomposition of $PCl_5(g)$ to $PCl_3(g)$ and $Cl_2(g)$, using the data given in the table.
Include a sign and units in your answer. **(2)**

	Enthalpy change / kJ mol^{-1}
$\Delta_f H$ [$PCl_5(s)$]	–443.5
$\Delta_f H$ [$PCl_3(l)$]	–319.7
$\Delta_v H$ [$PCl_5(s)$]	+64.9
$\Delta_v H$ [$PCl_3(l)$]	+30.5

(b) Another source gave a different value for the enthalpy change of this reaction.

$$PCl_5(g) \ \square \ PCl_3(g) + Cl_2(g) \quad \Delta_r H = +87.9 \text{ kJ mol}^{-1}$$

Explain the effect, if any, of increasing the temperature on the position of the equilibrium at constant volume. **(2)**

....

....

....

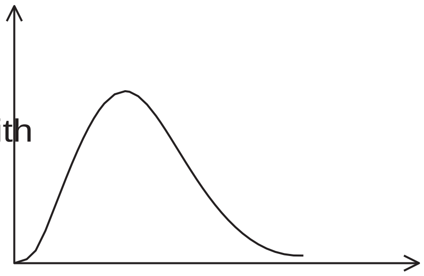
....

....

P 6 7 0 8 4 A 0 3 2 8

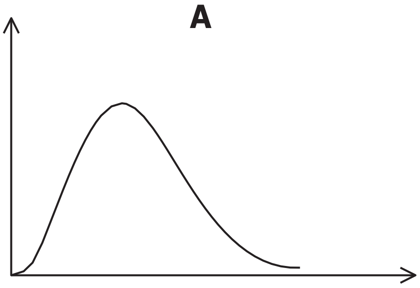
(Total for Question 2 = 7 marks)

3 The Maxwell-Boltzmann distribution of molecular energies for the reactant molecules in an uncatalysed reaction is shown.

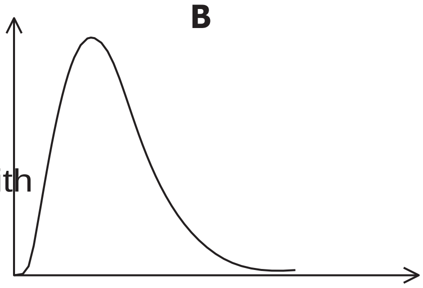


Which of these Maxwell-Boltzmann distributions would you expect for the same molecules in the presence of a catalyst at the same temperature and pressure? All diagrams are drawn to the same scale.

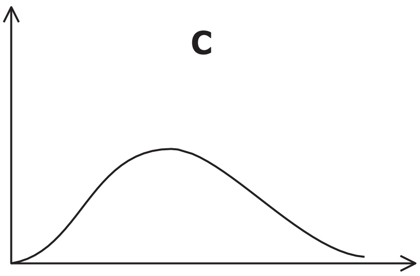
☒ **A**



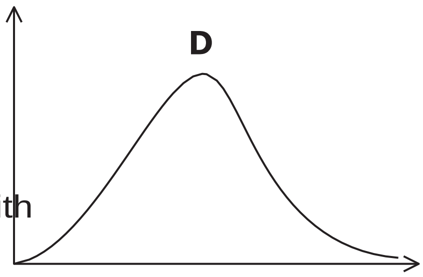
☒ **B**



☒ **C**



☒ **D**



(Total for Question 3 = 1 mark)

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4 When solid calcium sulfate dihydrate, $CaSO_4{\cdot}2H_2O$, is heated in a crucible, it forms solid calcium sulfate hemihydrate, $CaSO_4{\cdot}\frac{1}{2}H_2O$.

(a) Write an equation, including state symbols, for this reaction.

(1)

(b) Which two terms could be used to describe this reaction?

(1)

		Enthalpy change	Type of process
☒	**A**	endothermic	hydration
☒	**B**	exothermic	hydration
☒	**C**	exothermic	dehydration
☒	**D**	endothermic	dehydration

(c) When water is added to calcium sulfate hemihydrate, there is a rise in temperature.

A student decided to investigate this reaction using the following procedure:

Step **1** 10 cm^3 of distilled water is measured using a measuring cylinder having an uncertainty of ±0.5 cm^3, and is placed in an insulated cup with a lid.

Step **2** A thermometer with an uncertainty of ±0.5 °C is placed in the water.

Step **3** Exactly 10.00 g of calcium sulfate hemihydrate is weighed out using a balance with an uncertainty of ±0.005 g.

Step **4** The weighed quantity of calcium sulfate hemihydrate is added to the water in the insulated cup.

Step **5** The mixture in the insulated cup is stirred until no further temperature change is observed.

Results

Temperature of the water before adding the solid = 23.5

°C Maximum temperature of the mixture after adding the solid

= 26.3 °C **Other data**

Molar mass of calcium sulfate hemihydrate, $CaSO_4{\cdot}\frac{1}{2}H_2O$ =

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145.2 g mol^{-1} Density of water = 1.00 g cm^{-3}

(i) Calculate the minimum volume of water needed to convert 10.00 g of $CaSO_4{\cdot}\frac{1}{2}H_2O$ into $CaSO_4{\cdot}2H_2O$.

(2)

(ii) Calculate the enthalpy change, in $kJ\,mol^{-1}$, for this reaction. Include a sign in your answer and give your answer to an appropriate number of significant figures.

Assume that the liquid has a mass of 10.00 g and a specific heat capacity of $4.18\,J\,g^{-1}\,°C^{-1}$.

(4)

(iii) Deduce which measurement has the greatest uncertainty in this experiment. Justify your answer by calculating the percentage uncertainty of this piece of apparatus.

(2)

(Total for Question 4 = 10 marks)

5 This question concerns the combustion of fossil fuels in power stations.

(a) One type of power station uses the combustion of methane gas to generate power.

Write an equation for the incomplete combustion of methane gas to form carbon monoxide and water only. State symbols are not required.

(2)

(b) One of the problems associated with the combustion of some fossil fuels is the production of acidic gases, including the oxides of nitrogen and sulfur.

(i) Explain how oxides of sulfur and nitrogen can be formed from the combustion of fossil fuels.

(2)

(ii) Some power stations use a process of flue gas desulfurisation (FGD) to remove sulfur oxides from the gaseous combustion products.
One such process, known as wet scrubbing, uses a mixture of calcium carbonate and water to react with sulfur dioxide.

Two relevant equations are

$$SO_2(g) + CaCO_3(s) \rightarrow CaSO_3(s) + CO_2(g)$$

$$CaSO_3(s) + 2H_2O(l) + \tfrac{1}{2}O_2(g) \rightarrow CaSO_4{\cdot}2H_2O(s)$$

Explain why this process is an incomplete solution to the problem of burning fossil fuels.
Use the equations provided to illustrate your answer.

(2)

(c) Draw a dot-and-cross diagram for sulfur dioxide, showing outer electrons only.

(1)

(Total for Question 5 = 7 marks)

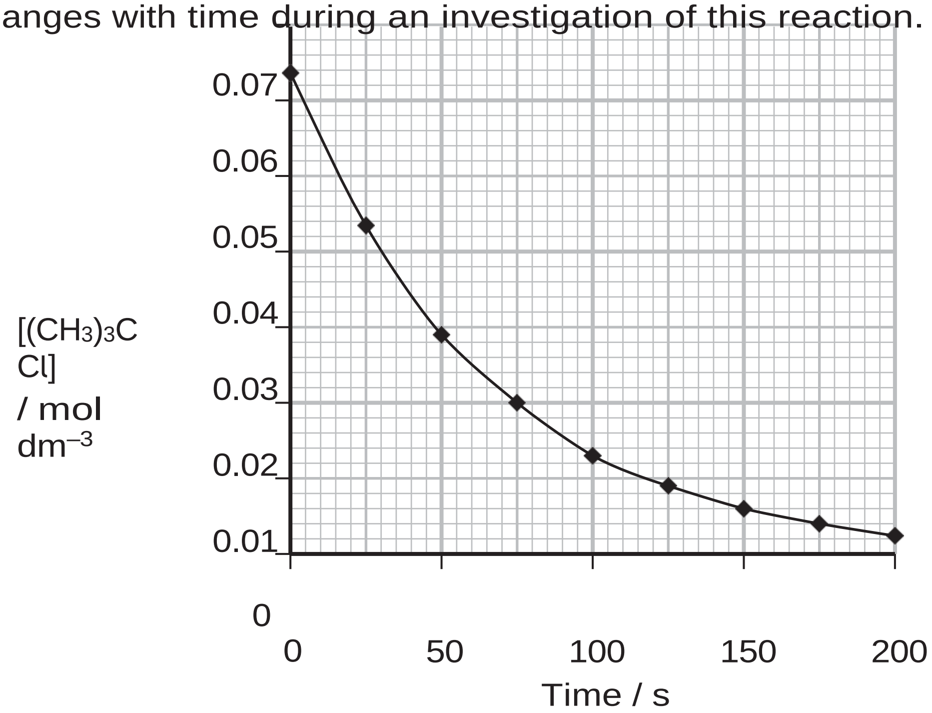
6 This question is about halogenoalkanes.

2-chloro-2-methylpropane can be hydrolysed by water.

The equation for this reaction is

$$(CH_3)_3CCl + H_2O \rightarrow (CH_3)_3COH + H^+ + Cl^-$$

The graph shows how the concentration of 2-chloro-2-methylpropane changes with time during an investigation of this reaction.



(a) Calculate the rate of reaction at 50 s. Show your working on the graph. Include units with your final answer.

(3)

Rate of reaction at 50 s = ...

(b) What is the classification of the mechanism for the hydrolysis of 2-chloro-2-methylpropane by water?

(1)

- ☒ **A** addition
- ☒ **B** elimination
- ☒ **C** free radical substitution
- ☒ **D** nucleophilic substitution

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(c) The letters X, Y and Z refer to three different halogenoalkanes:

X 1-bromobutane

Y 2-bromobutane

Z 2-bromo-2-methylpropane

1 cm^3 of each of these halogenoalkanes was added to separate test tubes containing 5 cm^3 of ethanol and 5 cm^3 of aqueous silver nitrate solution in a water bath at 50 °C.

(i) State the visible change in the reaction of an ethanol/silver nitrate solution with halogenoalkane X.
Include the **formula** of the compound responsible for this observation.

(2)

....

....

(ii) The three halogenoalkanes were placed in order of **decreasing** rate of reaction. Which is the correct sequence?

(1)

☒ **A** X, Z, Y

☒ **B** Z, X, Y

☒ **C** Z, Y, X

☒ **D** X, Y, Z

(d) Under different conditions, 2-chloro-2-methylpropane can react to produce 2-methylpropene, $(CH_3)_2C=CH_2$.

(i) State the reagent and conditions needed for this reaction. **(2)**

(ii) Draw the displayed formula for the repeat unit of a polymer that is made by the polymerisation of 2-methylpropene, $(CH_3)_2C=CH_2$. **(1)**

(iii) Draw a mechanism for the addition of hydrogen bromide, HBr, to 2-methylpropene to form 2-bromo-2-methylpropane.
Include curly arrows, and any relevant dipoles and lone pairs. **(4)**

(Total for Question 6 = 14 marks)

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7 This question is about the solubility of some alcohols.
The table shows the solubility in water of the first six alcohols in a homologous series.

Alcohol	Solubility / g dm^{-3}
methanol	soluble in all proportions
ethanol	soluble in all proportions
propan-1-ol	soluble in all proportions
butan-1-ol	632
pentan-1-ol	22
hexan-1-ol	5.9

(a) State what is meant by a homologous series.

You may use the alcohols in the table to illustrate your answer.

(1)

....

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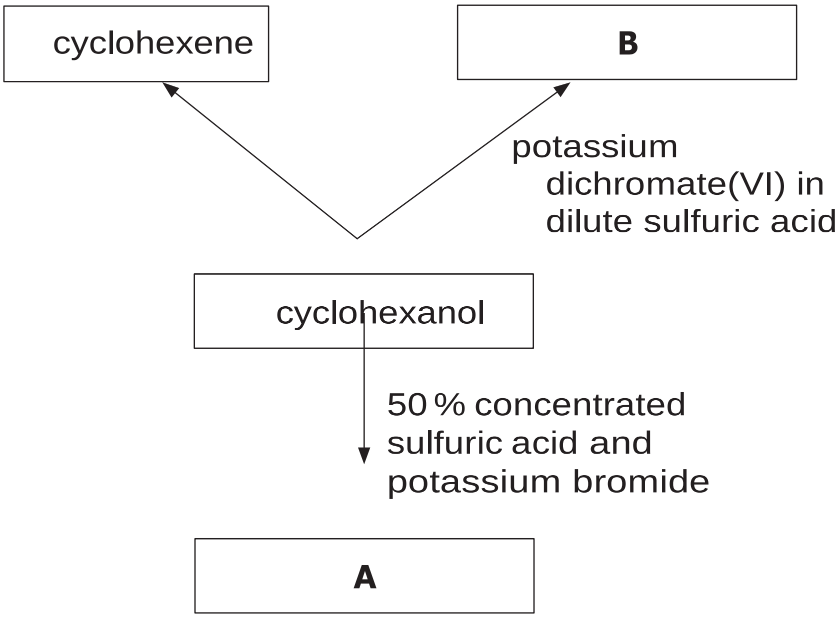
(b) Explain why methanol and water are 'soluble in all proportions'. You must include a diagram in your answer.

(3)

(Total for Question 7 = 4 marks)

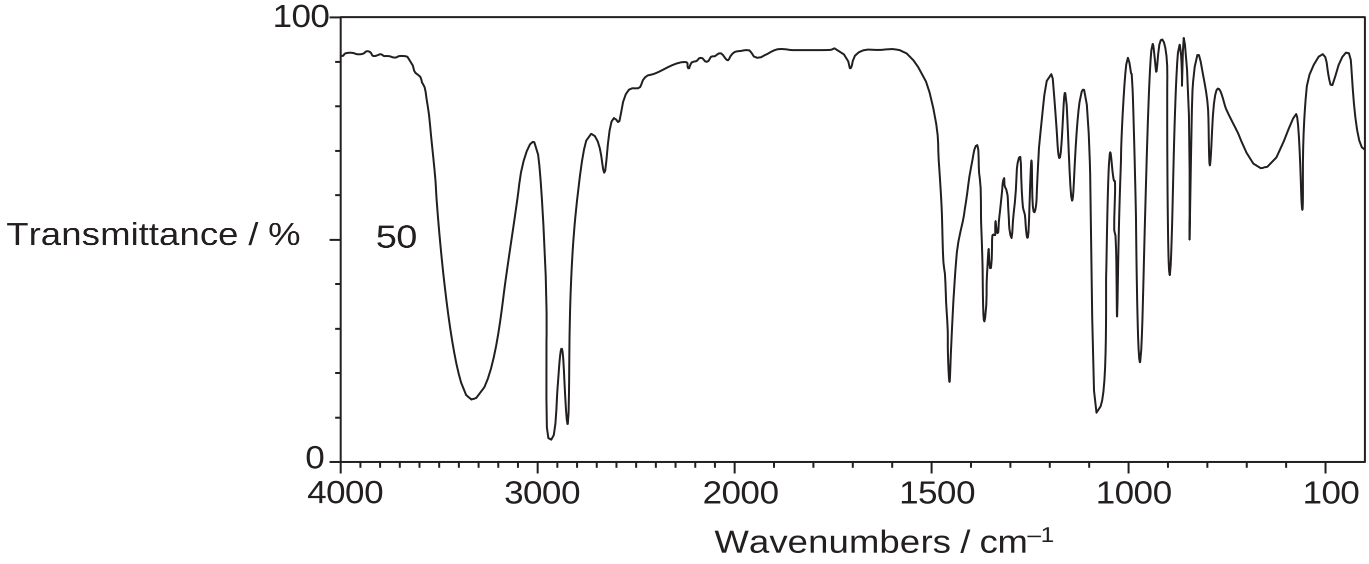
8 This question is about some reactions of cyclohexanol.



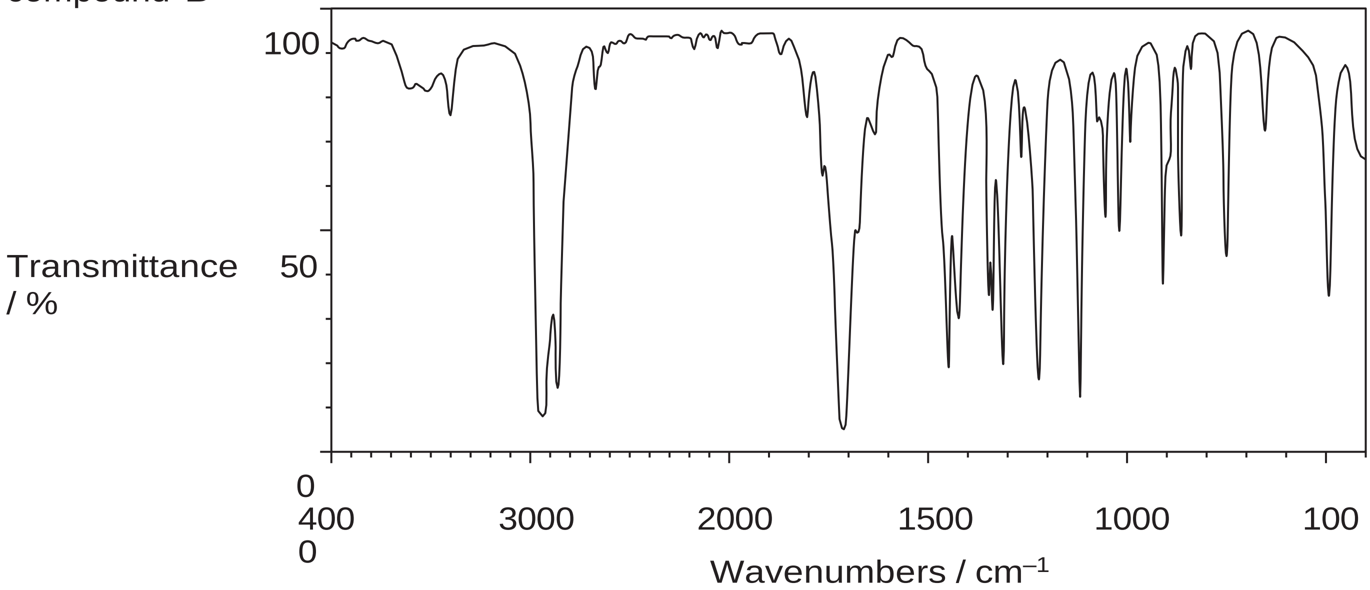
(a) Write the **skeletal** formula of compound **A**. **(1)**

(b) (i) Give the name **and** displayed formula of compound **B**. **(2)**

(ii) The infrared (IR) spectra of cyclohexanol and compound **B** are shown. IR Spectrum of cyclohexanol



IR Spectrum of compound **B**



Identify the bonds, using **both** IR spectra, that help to confirm the reaction of cyclohexanol to produce compound **B**.

Your answer must include the wavenumber ranges of any relevant bonds.

(2)

....

....

....

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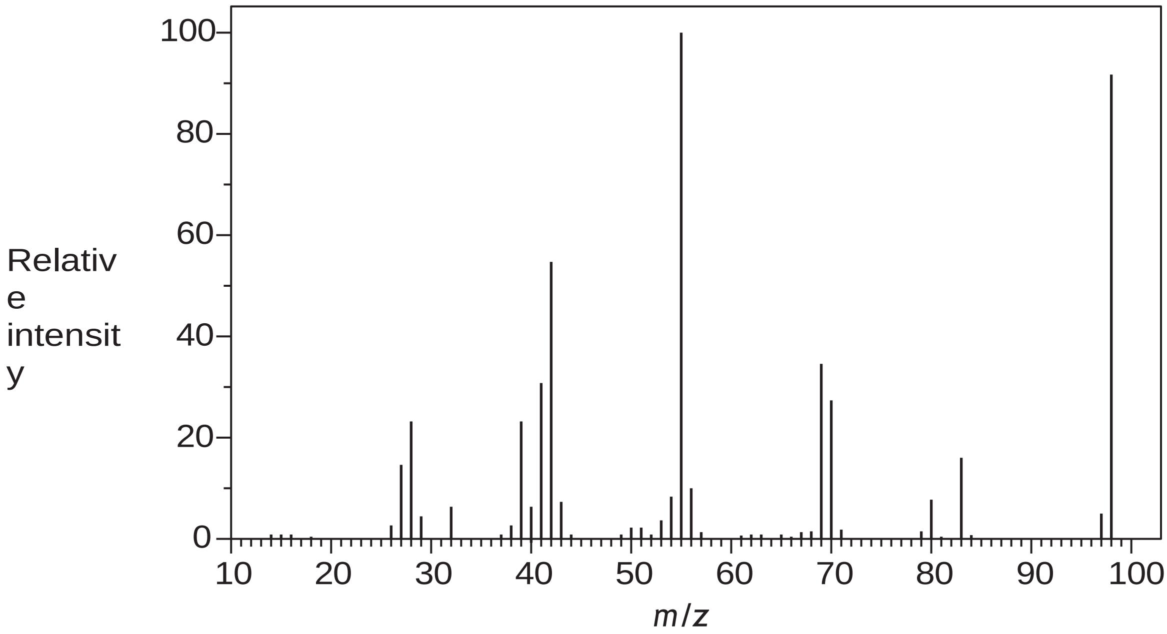
(iii) The mass spectrum of compound **B** is shown.



Deduce the relative molecular mass of compound **B** using the mass spectrum. Justify your answer.

(1)

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(iv) In the mass spectrum of cyclohexanol, there is a peak at $m/z = 83$. Give the formula of a fragment that could be responsible for this peak.

(2)

(c) (i) Cyclohexanol can be converted to cyclohexene. What is the classification for this reaction?

(1)

☒ **A** addition

☒ **B** elimination

☒ **C** oxidation

☒ **D** substitution

(ii) In an experiment, 10.0 cm^3 of cyclohexanol was converted to cyclohexene with a 63.0 % yield.

Compound	Molar mass / $g\ mol^{-1}$	Density / $g\ cm^{-3}$
cyclohexanol	100	0.962
cyclohexene	82.0	0.811

(4)

Calculate the volume of cyclohexene produced.

*(iii) Cyclohexene can be prepared by reacting cyclohexanol with phosphoric(V) acid.

The mixture is warmed in a water bath for 15 minutes before distilling off a mixture of cyclohexene and water.

Devise a procedure to obtain a pure, dry sample of cyclohexene from the distillate. Include a reason for each step.

[Boiling temperature of cyclohexene = 83 °C Density of cyclohexene = 0.811 g cm^{-3}]

(6)

(Total for Question 8 = 19 marks)

9 An equation for the formation of ammonia using the Haber process is shown.

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

(a) (i) Calculate the enthalpy change for the forward reaction shown in the equation, selecting from the bond enthalpies in the table.
Include a sign in your answer.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
N—N	158
N═N	410
N≡N	945
N—H	391
H—H	436

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(ii) A data book gives the standard enthalpy change of formation of ammonia as –46.1 kJ mol^{-1}.

Give two reasons for the difference between this value and the value that you calculated in (a)(i).

(2)

Reason 1

....

....

....

Reason 2

....

....

....

(iii) What is the percentage atom economy, by mass, for ammonia in the forward reaction?

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

(1)

A 17.6 %

B 50.0 %

C 82.4 %

D 100 %

(iv) What is the equilibrium expression for K_c?

(1)

A $K_c = \frac{[N_2][3H_2]}{[2NH_3]}$

B $K_c = \frac{[2NH_3]}{[N_2][3H_2]}$

C $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

D $K_c = \frac{[N_2][H_2]^3}{[NH_3]^2}$

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(b) In the chemical industry, many processes involve reversible reactions. The product is often removed before equilibrium is attained.

Give three reasons why the product may be removed before its maximum concentration is achieved.

(3)

(c) Ammonia is stable in air but can be oxidised on the surface of a copper catalyst. An equation for this reaction is

$$4NH_3(g) + 5O_2(g) \rightarrow 6H_2O(g) + 4NO(g) \qquad \Delta_r H = -905.2\ \text{kJ mol}^{-1}$$

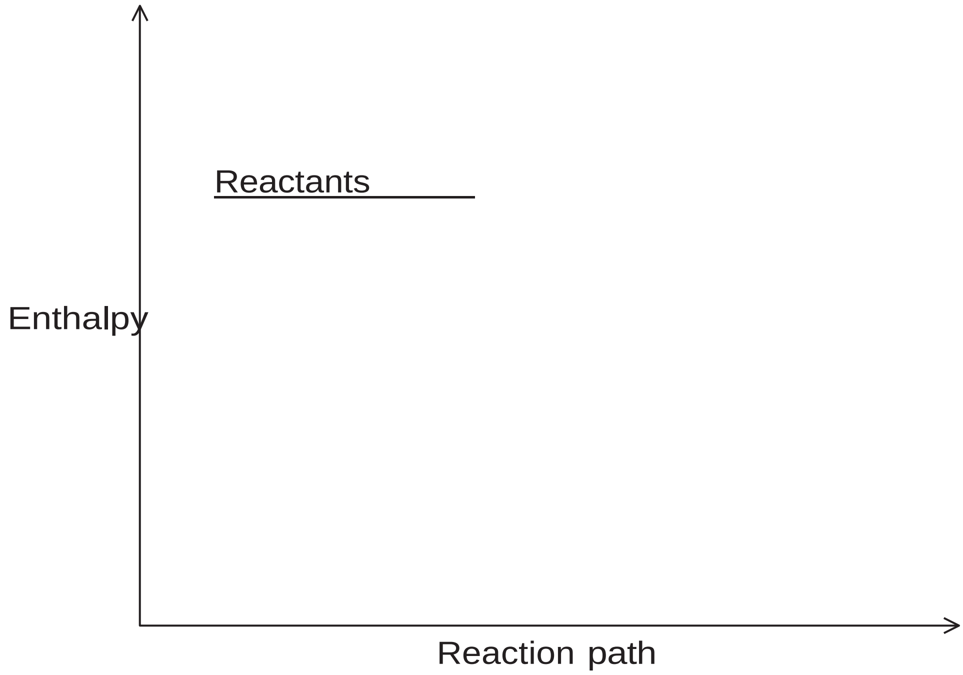
The catalyst is usually warmed to approximately 300 °C to start the reaction, but after a short reaction time the copper catalyst often melts.

(i) Give a reason why the catalyst is warmed and a reason why the catalyst may melt.

(2)

(ii) Complete the reaction profile for this catalysed oxidation of ammonia, showing the enthalpy change, $\Delta_r H$.

(2)



(iii) Describe the processes that occur on the surface of a heterogeneous catalyst during the oxidation of ammonia in air.

(3)

(Total for Question 9 = 17 marks)

TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										(18) 4.0 **He** helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103