Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Time 1 hour 30 minutes

Paper reference **8CH0/02**

Chemistry

Advanced Subsidiary
PAPER 2: Core Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or 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.

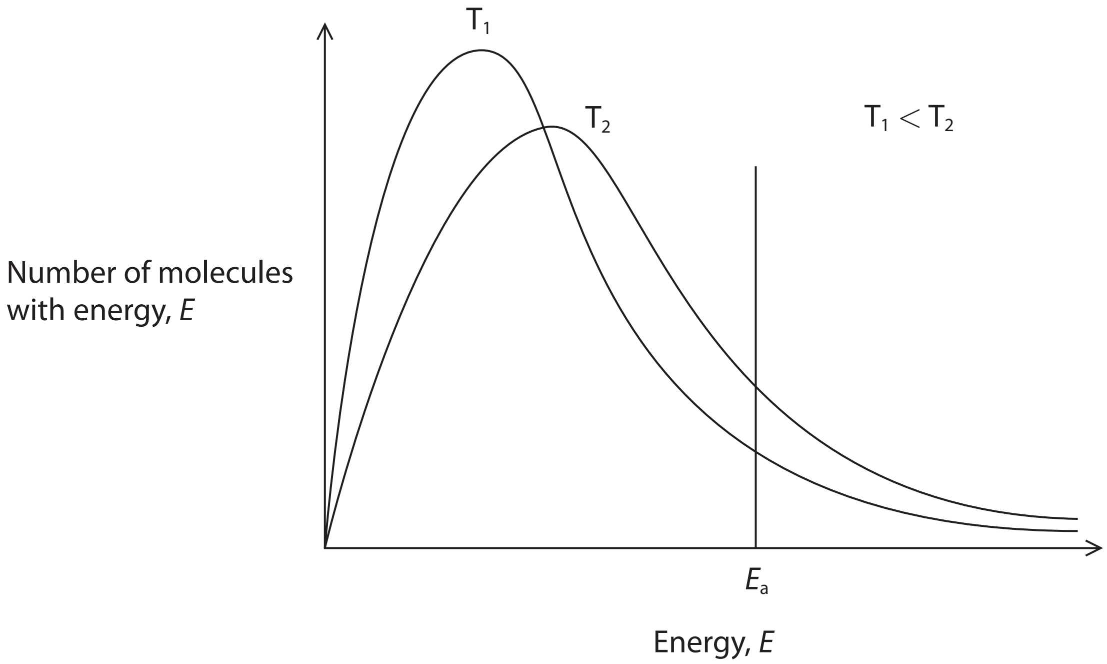
Turn over ▶

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 This question is about reaction kinetics.

(a) Maxwell-Boltzmann distributions of the molecular energies of particles in a gas are shown at two different temperatures.
The activation energy for the reaction, E_a, is labelled.



(i) The activation energy is the minimum energy required **(1)**

☐ **A** for a reaction to take place when reactant molecules collide

☐ **B** for reactant molecules to collide

☐ **C** for all collisions to result in a reaction

☐ **D** for the particles to collide with the appropriate orientation

P 7 0 8 0 9 R A 0 2 2 8

(ii) Explain, with reference to the gaseous particles, the differences in the two distributions.

(2)

....

....

....

....

....

....

(iii) Which of the following is **not** an explanation of why increasing the temperature increases the rate of a reaction?

(1)

☒ **A** the area under the curve to the right of E_a is larger at a higher temperature

☒ **B** a greater percentage of collisions are successful at a higher temperature

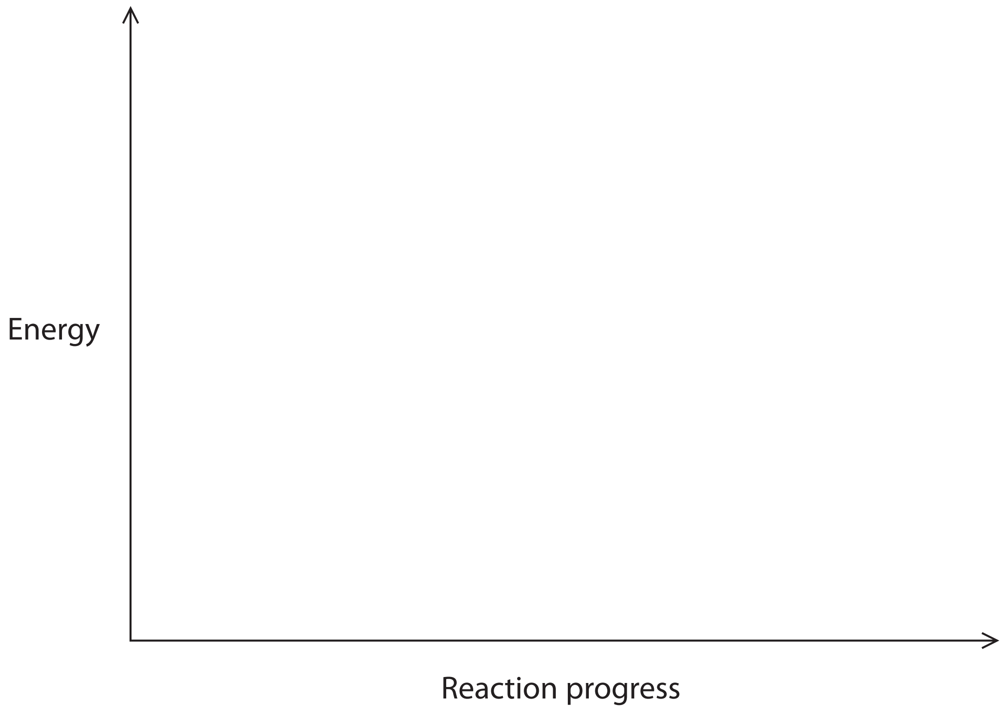
☒ **C** molecules move faster and collide more often at a higher temperature

☒ **D** there are more collisions, all of which are successful, at a higher temperature

(b) Reaction profiles can be used to show the effect of the addition of a catalyst on the energy changes during the course of a reaction.

(i) Draw fully labelled reaction profiles for the reaction both with and without a catalyst for an exothermic reaction.

(4)



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

(1)

....

....

(c) A heterogeneous catalyst is often added to a reaction between gases.

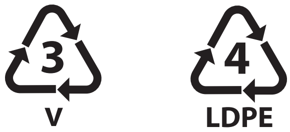
A heterogeneous catalyst

(1)

- ☒ **A** increases the rate without taking part in the reaction
- ☒ **B** increases the yield of the reaction at equilibrium
- ☒ **C** is in the same phase as the reaction mixture
- ☒ **D** is often a porous material, so increasing the surface area

(Total for Question 1 = 10 marks)

2 Plastic products often have a symbol on them. Two of the symbols are shown.



The symbols are used to sort the plastic products into groups of specific types of plastic when they are thrown away.

(a) Some plastic products can be cleaned and used again.

Give two other uses of waste plastic.

(2)

....

....

....

....

....

....

(b) The V on the symbol with the number 3 stands for vinyl or vinyl chloride.
The V is sometimes replaced by PVC, standing for polyvinyl chloride.

State the link between vinyl chloride and polyvinyl chloride.

(1)

....

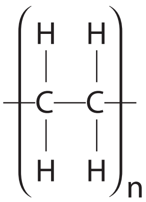
....

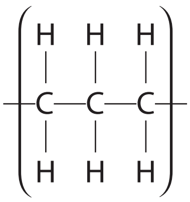
....

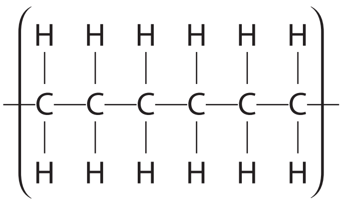
(c) LDPE stands for low density poly(ethene).

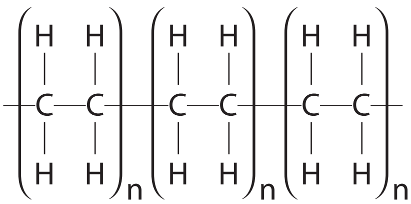
Which of the diagrams shows exactly three repeat units of poly(ethene)?

(1)

☒ **A** 

☒ **B** 

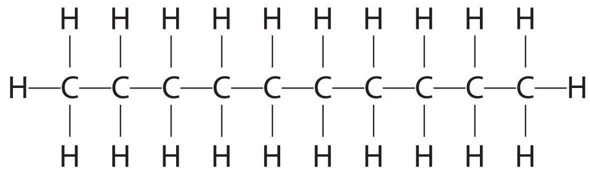
☒ **C** 

☒ **D** 

(Total for Question 2 = 4 marks)

3 Decane, $C_{10}H_{22}$, is an alkane present in petrol and kerosene.

It has the displayed formula



The enthalpy change of combustion, $\Delta_c H^{\ominus}$, of decane can be estimated using mean bond enthalpy values and the equation shown.

$$C_{10}H_{22}(l) \; + \; 15.5O_2(g) \; \rightarrow \; 10CO_2(g) \; + \; 11H_2O(l)$$

(a) (i) Calculate the enthalpy change of combustion of decane, using the mean bond enthalpy values in the table.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
O=O	498
C=O	805
O—H	464

(ii) A data book value for the enthalpy change of combustion of decane is $-6778 \text{ kJ mol}^{-1}$.

Give two reasons for the difference between your answer to (a)(i) and this value.

(2)

....

....

....

....

....

(b) Catalytic converters in cars remove unwanted substances such as nitrogen monoxide, carbon monoxide and unreacted hydrocarbons from the exhaust fumes.

The formula of the nitrogen monoxide free radical can be written as NO•

(i) Which is true for the NO• free radical?

(1)

☒ **A** NO• is formed during thermal decomposition of $LiNO_3$

☒ **B** NO• has a total of 15 protons, 15 neutrons and 16 electrons

☒ **C** NO• is a species with an unpaired electron

☒ **D** NO• is formed by heterolytic fission

(ii) It has been suggested that unreacted hydrocarbons and nitrogen monoxide are removed in a catalytic converter by reacting them together.

The reaction between decane and nitrogen monoxide produces carbon dioxide, water and nitrogen as the only products.

Complete the balanced equation for this reaction.
State symbols are not required.

(2)

.... $C_{10}H_{22}$ + ... NO $\rightarrow$

(iii) Give a possible reason why this reaction might not proceed according to the equation in (b)(ii).

(1)

....

....

....

(Total for Question 3 = 9 marks)

4 A thermometric titration is a method for finding the end-point of a titration between aqueous solutions of ammonia and ethanoic acid.

A thermometric titration was carried out using the following steps:

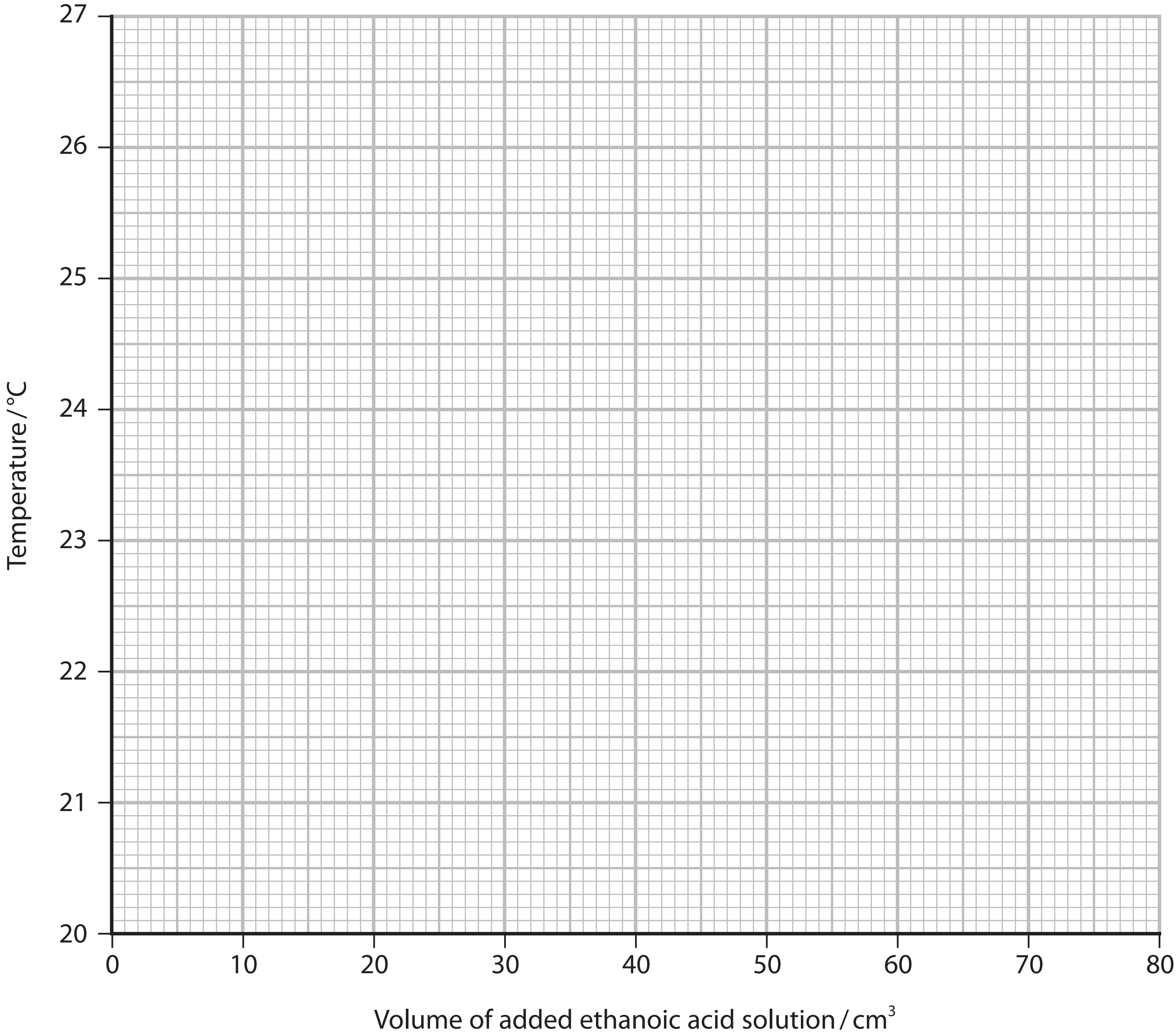
- the temperatures of the aqueous ammonia and ethanoic acid solutions were measured and found to be 20.1 °C
- 30 cm^3 of the aqueous ammonia was placed in a polystyrene cup
- a 10 cm^3 portion of an ethanoic acid solution, concentration 1.10 mol dm^{-3}, was added to the polystyrene cup, the mixture stirred and the temperature measured
- further 10 cm^3 portions of ethanoic acid solution were added, the mixture stirred, and the temperature measured immediately after each addition, until a total of 80 cm^3 had been added.

(a) Results for this experiment are shown in the table.

Volume of ethanoic acid added / cm^3	0	10	20	30	40	50	60	70	80
Temperature / °C	20.1	21.8	23.5	25.1	26.4	25.8	24.9	24.1	23.3

(i) Plot the results using the axes provided.
Include two straight lines of best fit, extrapolated until they meet.

(2)



(ii) Determine the maximum temperature rise from your graph.

(1)

....

(iii) Calculate the number of moles of ethanoic acid, with a concentration of 1.10 mol dm^{-3}, added at the end-point of the reaction.

(2)

(iv) The reaction that occurs is

$$NH_3(aq) + CH_3COOH(aq) \rightarrow NH_4^+(aq) + CH_3COO^-(aq)$$

Calculate the enthalpy change per mole for this reaction.
Include a sign and units in your answer.

[Assume:
specific heat capacity of the solution at the end-point = 4.18 $J\,g^{-1}\,°C^{-1}$
1.00 cm^3 of the solution at the end-point has a mass of 1.00 g]

(3)

(b) (i) The temperature of the reaction mixture initially increased because the reaction is

(1)

☒ **A** endothermic so energy is absorbed by the water

☒ **B** endothermic so energy is released by the water

☒ **C** exothermic so energy is absorbed by the water

☒ **D** exothermic so energy is released by the water

(ii) Give the main reason why, after the end-point was reached, the temperature of the solution decreased.

(1)

....

....

....

(Total for Question 4 = 10 marks)

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

5 Chloroalkanes can be formed from both alkenes and alkanes.

(a) Ethene can be converted into chloroethane.

(i) Identify, by name or formula, the reagent for this conversion.

(1)

....

(ii) Draw the mechanism for the conversion of ethene into chloroethane.

Include curly arrows, and any relevant lone pairs and dipoles.

(4)

(b) Ethane can also be converted into chloroethane.

(i) Give the reagent and condition required to convert ethane into chloroethane. **(1)**

Reagent ....

Condition ....

(ii) What is the mechanism and type of reaction by which ethane is converted into chloroethane? **(1)**

☒ **A** electrophilic addition

☒ **B** free radical addition

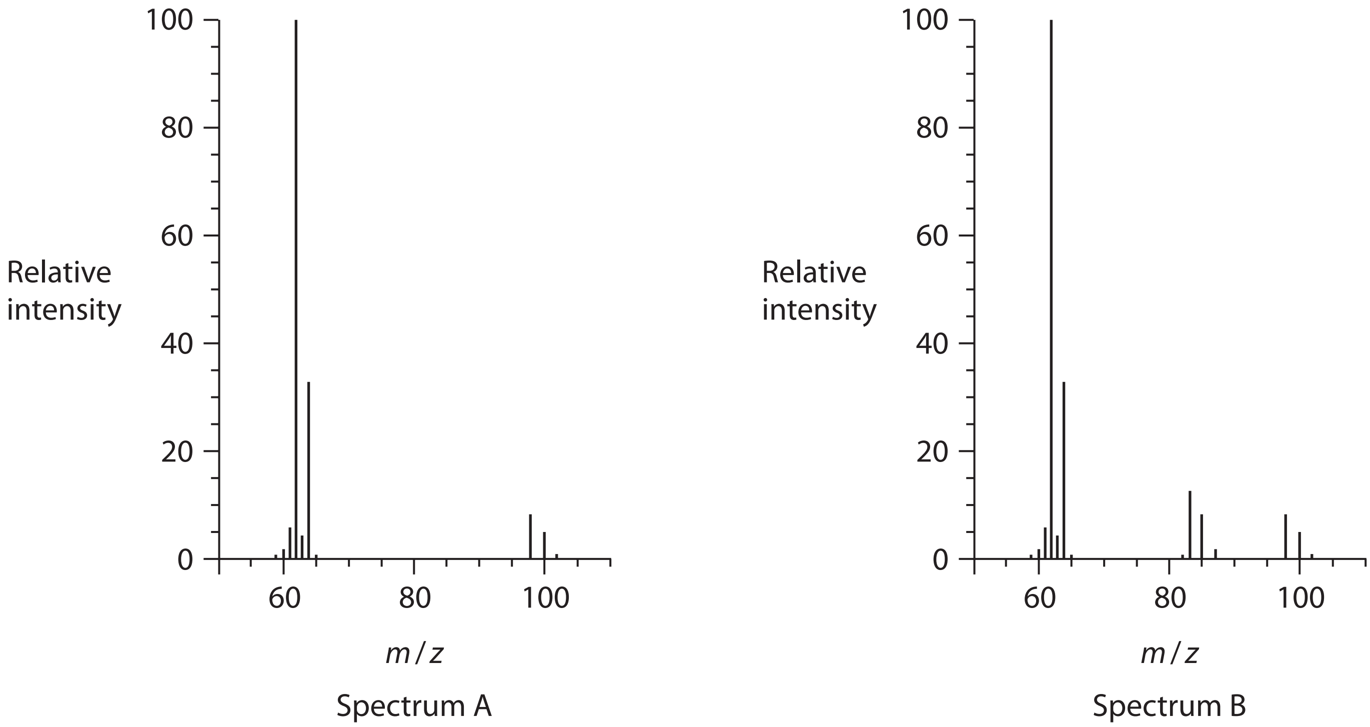
☒ **C** free radical substitution

☒ **D** nucleophilic substitution

(iii) Further reactions of chloroethane result in the formation of small amounts of the isomers 1,1-dichloroethane and 1,2-dichloroethane.

Write equations to show the formation of these products.
Curly arrows are not required. **(3)**

(iv) The mass spectra of the two isomers of dichloroethane are shown.



Deduce the molecular formulae of the species responsible for the molecular ion peaks at *m* / *z* 98, 100 and 102.
The molecular formulae for the species producing these peaks are the same in both spectra.

(2)

(v) State why in both spectra the peaks at 98, 100 and 102 have different relative intensities.

(1)

....

....

....

(vi) Explain how the presence of the peaks at 83, 85 and 87 in Spectrum B allows the identification of the isomer responsible for this spectrum.

(2)

....

....

....

....

....

....

....

(Total for Question 5 = 15 marks)

BLANK PAGE

6 The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

(a) Primary alcohols react very slowly with concentrated hydrochloric acid. State a different reagent for the chlorination of primary alcohols.

(1)

....

(b) In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature / °C	Density / $g\,cm^{-3}$
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

Draw a diagram of the separating funnel after 15 minutes, labelling the layer containing 2-chloro-2-methylpropane.

(2)

(c) After separation, the organic layer was shaken with sodium hydrogencarbonate solution. Fizzing was observed.

(i) Identify, by name or formula, the gas that was given off.

(1)

....

(ii) Give the **formula** of the ion that reacted with the hydrogencarbonate ion to form the gas.

(1)

....

(iii) Describe how to dry the organic layer to prepare it for distillation. Include the name of a suitable drying agent.

(2)

....

....

....

....

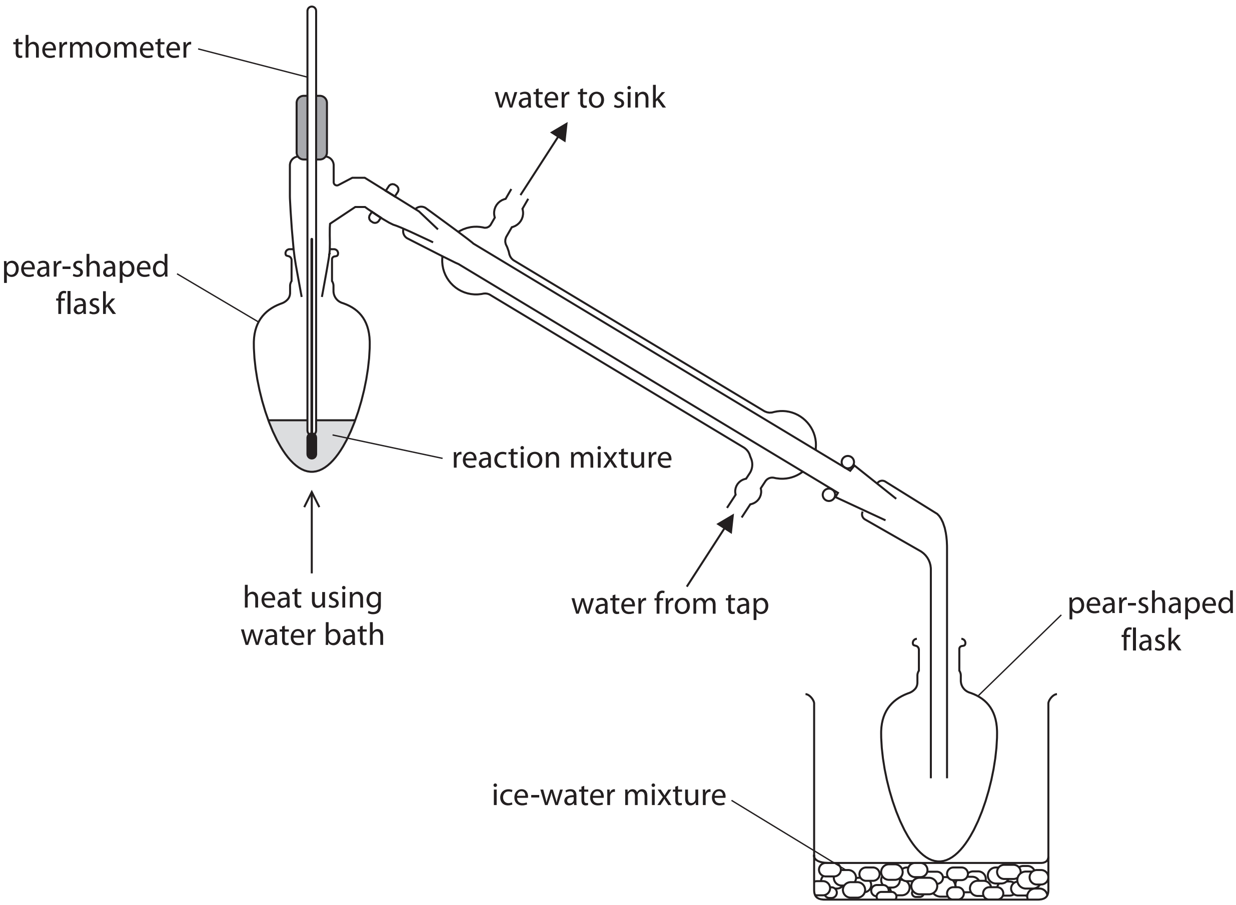
(d) The dried 2-chloro-2-methylpropane was transferred to the distillation apparatus.

(i) State the appropriate temperature range over which to collect the product.

(1)

....

*(ii) A diagram of the distillation apparatus is shown.



Discuss the improvements that should be made to the set-up of the apparatus. Include the likely effect of the errors identified on the yield or purity of the product.
Assume the apparatus is suitably clamped.

(6)

....

....

....

....

....

....

....

....

....

(e) 11.6 cm^3 of 2-chloro-2-methylpropane was collected from 12.0 g of 2-methylpropan-2-ol.

Calculate the percentage yield using the data in the table.

(4)

Substance	Density / $g\,cm^{-3}$	Molar mass / $g\,mol^{-1}$
2-methylpropan-2-ol	0.79	74
2-chloro-2-methylpropane	0.84	92.5

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(f) Infrared spectroscopy can be used to determine the purity of a substance.

(i) State how infrared spectroscopy could be used to show that no 2-methylpropan-2-ol was present in the distillate.

(1)

....

....

....

(ii) Give one advantage and one disadvantage of using a chemical test rather than infrared spectroscopy to determine whether any of the 2-methylpropan-2-ol remained.

(2)

....

....

....

....

....

....

(Total for Question 6 = 21 marks)

7 Nitrogen monoxide and chlorine gases react together to form a single product, nitrosyl chloride, $NOCl$.

Below 100 °C the yield of $NOCl$ is almost 100 %, but as the temperature rises the yield of $NOCl$ decreases as the equilibrium position shifts to the left.

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g) \qquad \Delta_r H^{\ominus} = -75.6\ \text{kJ mol}^{-1}$$

(a) A 1 dm^3 reaction vessel, initially containing 2 mol of NO and 1 mol of Cl_2, was allowed to come to equilibrium at 225 °C to produce 1.82 mol of $NOCl$.

(i) Calculate the number of moles of NO and Cl_2 at equilibrium.

(2)

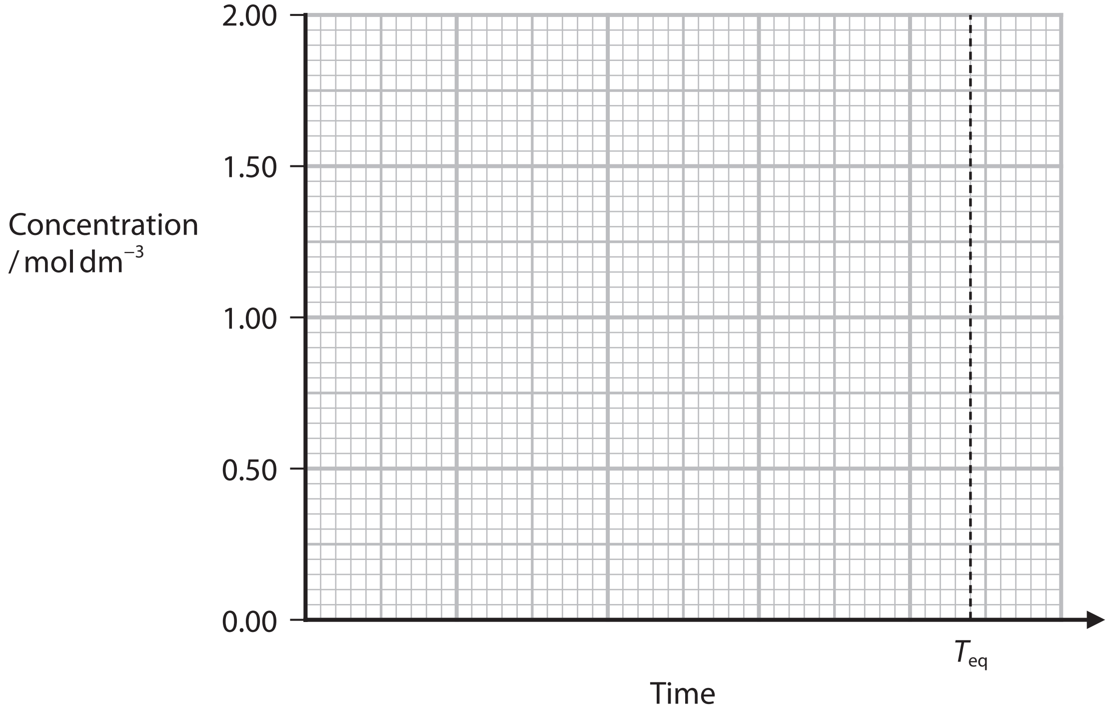
Moles of NO ....

Moles of Cl_2 ....

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(ii) Sketch three lines showing the change in concentration over time of the three components of the reaction using the axes given.
You should assume that the reaction reaches equilibrium at time T_{eq}.

(3)



(iii) The expression for the equilibrium constant, K_c, for this reaction is

(1)

☒ **A** $K_c = \dfrac{2[NOCl]}{2[NO][Cl_2]}$

☒ **B** $K_c = \dfrac{[NOCl]^2}{[NO]^2[Cl_2]}$

☒ **C** $K_c = \dfrac{2[NO][Cl_2]}{2[NOCl]}$

☒ **D** $K_c = \dfrac{[NO]^2[Cl_2]}{[NOCl]^2}$

(iv) Give the reason why the equilibrium yield of NOCl decreases when the temperature changes from 25 °C to 225 °C.

The enthalpy change for the reaction at 25 °C is $-75.6\,kJ\,mol^{-1}$.

(1)

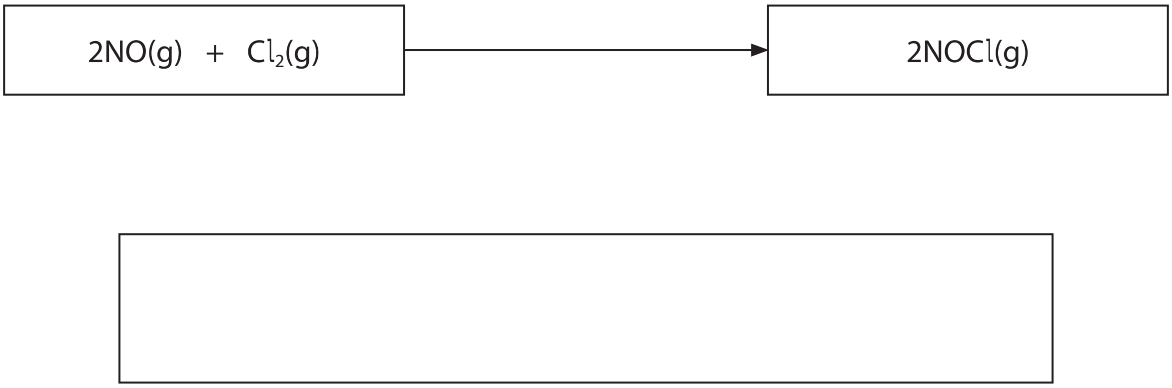
....

....

....

(b) (i) Complete the Hess cycle to enable you to calculate the enthalpy change of formation, $\Delta_f H^{\ominus}_{298}$, of NOC*l*.
Include state symbols.

(2)



(ii) Calculate the enthalpy change of formation, $\Delta_f H^{\ominus}_{298}$, of NOC*l* given the data

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g) \qquad \Delta_r H^{\ominus}_{298} = -75.6\ kJ\ mol^{-1}$$

enthalpy change of formation of NO, $\Delta_f H^{\ominus}_{298}$, $= +90.3\ kJ\ mol^{-1}$

(2)

(Total for Question 7 = 11 marks)

TOTAL FOR PAPER = 80 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
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											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