

Chemistry
Advanced Subsidiary
PAPER 2: Core Organic and Physical Chemistry

Total Marks

Time: 1 hour 30 minutes

In the boxes below, write your name, centre number and candidate number.

Surname					
Other names					
Centre Number					
Candidate Number					

YOU MUST HAVE

Scientific calculator, Data Booklet, ruler

YOU WILL BE GIVEN

Diagram Booklet, Periodic Table

INSTRUCTIONS

Answer ALL questions.

Answer the questions in the spaces provided in this Question Paper or in the separate Diagram Booklet – 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 provided as a separate insert.

There may be spare copies of some diagrams.

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.

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) Look at the diagram for Question 1(a) in the Diagram Booklet. 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 mark)**

☐ **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**

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Turn over

1 continued.

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

(continued on the next page)

1 continued.

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

- ☐ **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**

(continued on the next page)

1 continued.

(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) Look at the diagram for Question 1(b)(i) in the Diagram Booklet. Draw fully labelled reaction profiles for the reaction both with and without a catalyst for an exothermic reaction.
(4 marks)**

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

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1 continued.

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

**A heterogeneous catalyst
(1 mark)**

- ☐ **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 Look at the symbols for Question 2 in the Diagram Booklet. 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 marks)**

(continued on the next page)

Turn over

2 continued.

- (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 marks)**

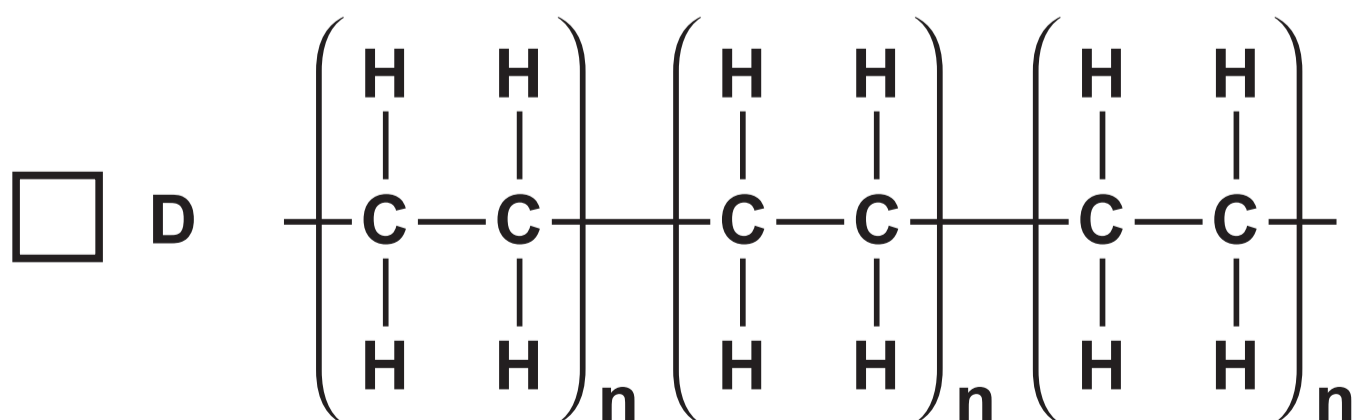
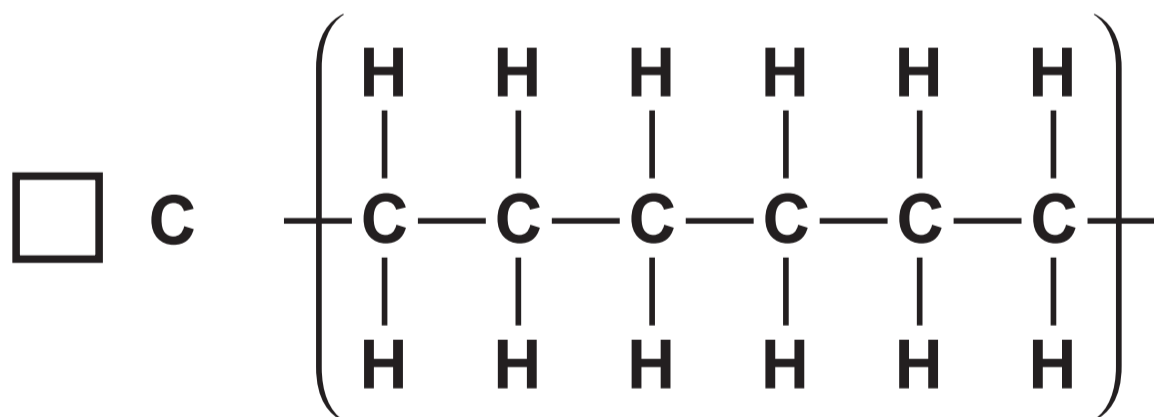
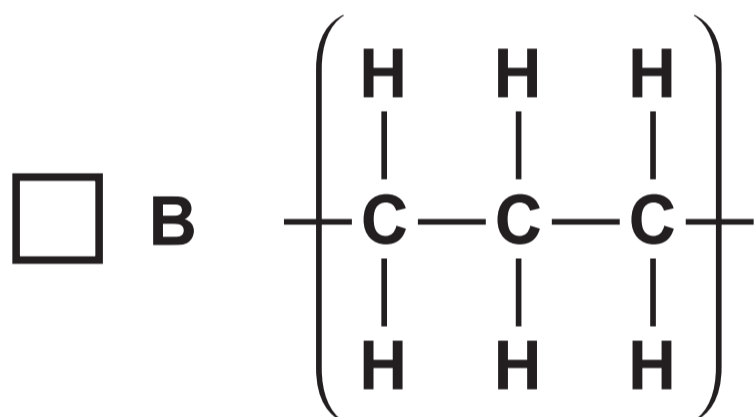
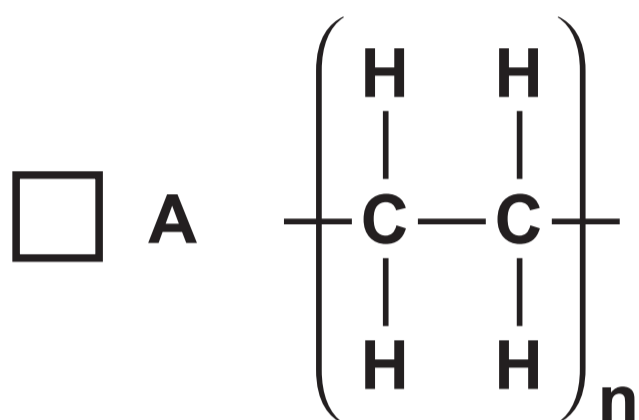
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2 continued.

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

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

(1 mark)

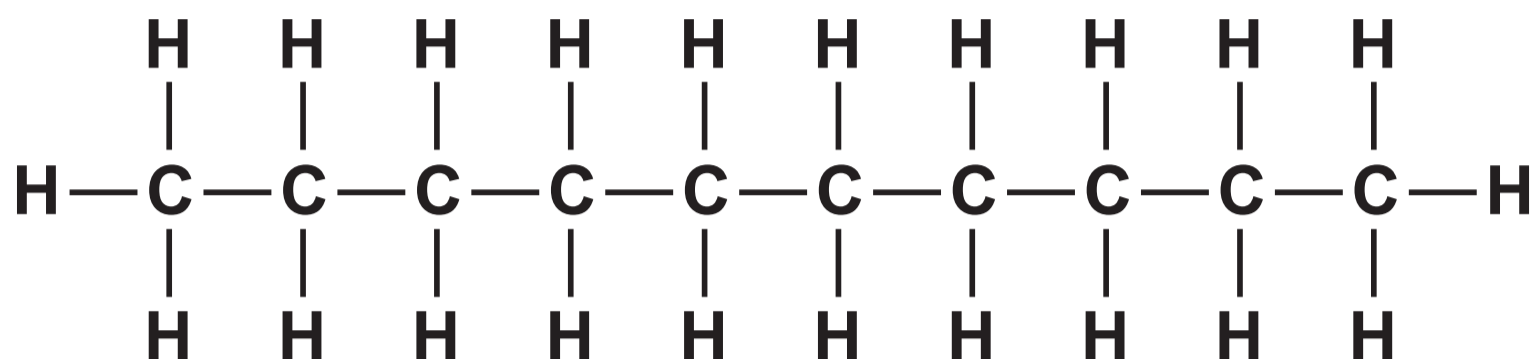


(Total for Question 2 = 4 marks)

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- 3 Decane, $\text{C}_{10}\text{H}_{22}$, 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.



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3 continued.

- (a) (i) Look at the table for Question 3(a)(i) in the Diagram Booklet. Calculate the enthalpy change of combustion of decane, using the mean bond enthalpy values in the table.
(3 marks)**

(continued on the next page)

Turn over

3 continued.

- (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 marks)**

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3 continued.

- (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 mark)**

- ☐ **A NO• is formed during thermal decomposition of LiNO₃**
- ☐ **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**

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3 continued.

- (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 marks)



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3 continued.

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

(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.**

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4 continued.

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

Volume of ethanoic acid added / cm³	0	10	20	30	40	50	60	70	80
Temperature / °C	20·0	22·0	23·5	25·0	26·5	26·0	25·0	24·0	23·5

- (i) Use the axes for Question 4(a)(i) in the Diagram Booklet to plot the results.**

**Include two straight lines of best fit, extrapolated until they meet.
(2 marks)**

- (ii) Determine the maximum temperature rise from your graph.
(1 mark)**

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4 continued.

- (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 marks)**

(continued on the next page)

4 continued.

(iv) The reaction that occurs is



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 = $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$
 1.00 cm^3 of the solution at the end-point has a mass of 1.00 g]
(3 marks)

(continued on the next page)

Turn over

4 continued.

(b) (i) The temperature of the reaction mixture initially increased because the reaction is (1 mark)

- ☐ **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**

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4 continued.

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

(Total for Question 4 = 10 marks)

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 mark)

(continued on the next page)

5 continued.

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

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

(4 marks)

(continued on the next page)

Turn over

5 continued.

(b) Ethane can also be converted into chloroethane.

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

Reagent

Condition

(continued on the next page)

5 continued.

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

- ☐ **A electrophilic addition**
- ☐ **B free radical addition**
- ☐ **C free radical substitution**
- ☐ **D nucleophilic substitution**

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5 continued.

- (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 marks)

5 continued.

(iv) Look at the diagram for Question 5(b)(iv) in the Diagram Booklet. Spectrum A shows the mass spectrum of one isomer of dichloroethane. The inset shows an enlargement of part of this spectrum.

Deduce the molecular formulae of the species responsible for the molecular ion peaks at m/z 98, 100 and 102.

(2 marks)

5 continued.

- (v) State why the peaks at 98, 100 and 102 have different relative intensities.
(1 mark)**

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5 continued.

(vi) Look at the diagram for Question 5(b)(vi) in the Diagram Booklet. Spectrum B shows the mass spectrum of the other isomer of dichloroethane. 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 marks)

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(Total for Question 5 = 15 marks)

- 6 The preparation of 2-chloro-2-methylpropane, $(\text{CH}_3)_3\text{CCl}$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(\text{CH}_3)_3\text{COH}$, a tertiary alcohol.



- (a) Primary alcohols react very slowly with concentrated hydrochloric acid. State a different reagent for the chlorination of primary alcohols. (1 mark)

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6 continued.

- (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

**On the next page, draw a diagram of the separating funnel after 15 minutes, labelling the layer containing 2-chloro-2-methylpropane.
(2 marks)**

(continued on the next page)

6 continued.

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6 continued.

(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 mark)**

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

(continued on the next page)

6 continued.

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

(continued on the next page)

6 continued.

(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 mark)**

(continued on the next page)

6 continued.

- *(ii) Look at the diagram for Question 6(d)(ii) in the Diagram Booklet. 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 marks)**

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- (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 marks)

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

(continued on the next page)

Turn over

6 continued.

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6 continued.

(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 mark)**

(continued on the next page)

6 continued.

- (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 marks)**

(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.



- (a) A 1 dm³ reaction vessel, initially containing 2 mol of NO and 1 mol of Cl₂, 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 Cl₂ at equilibrium.
(2 marks)

Moles of NO _____

Moles of Cl₂ _____

7 continued.

(ii) Use the axes for Question 7(a)(ii) in the Diagram Booklet to sketch three lines showing the change in concentration over time of the three components of the reaction. You should assume that the reaction reaches equilibrium at time T_{eq} . (3 marks)

(iii) The expression for the equilibrium constant, K_c , for this reaction is (1 marks)

☐ A $K_c = \frac{2[\text{NOCl}]}{2[\text{NO}][\text{Cl}_2]}$

☐ B $K_c = \frac{[\text{NOCl}]^2}{[\text{NO}]^2[\text{Cl}_2]}$

☐ C $K_c = \frac{2[\text{NO}][\text{Cl}_2]}{2[\text{NOCl}]}$

☐ D $K_c = \frac{[\text{NO}]^2[\text{Cl}_2]}{[\text{NOCl}]^2}$

(continued on the next page)

7 continued.

- (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 $-75.6 \text{ kJ mol}^{-1}$.
(1 mark)**

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7 continued.

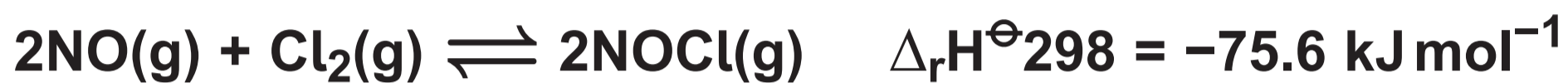
- (b) (i) Look at the diagram for Question 7(b)(i) in the Diagram Booklet. Complete the Hess cycle to enable you to calculate the enthalpy change of formation, $\Delta_f H^\ominus_{298}$, of NOCl.**

**Include state symbols.
(2 marks)**

(continued on the next page)

7 continued.

- (ii) Calculate the enthalpy change of formation, $\Delta_f H^\ominus_{298}$, of NOCl given the data (2 marks)**



**enthalpy change of formation of NO, $\Delta_f H^\ominus_{298}$,
= +90.3 kJ mol⁻¹**

(Total for Question 7 = 11 marks)

**TOTAL FOR PAPER = 80 MARKS
END OF PAPER**