A-level
Chemistry
(7405/2)
Paper 2: Organic and Physical Chemistry

Specimen 2015 v0.5 Session 2 hours

Materials
For this paper you must have:
• the Data Booklet, provided as an insert
• a ruler
• a calculator.

Instructions
• Answer all questions.
• Show all your working.

Information
• The maximum mark for this paper is 105.
This question involves the use of kinetic data to deduce the order of a reaction and calculate a value for a rate constant.

The data in Table 1 were obtained in a series of experiments on the rate of the reaction between compounds A and B at a constant temperature.

Table 1

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial concentration of A / mol dm(^{-3})</th>
<th>Initial concentration of B / mol dm(^{-3})</th>
<th>Initial rate / mol dm(^{-3}) s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.12</td>
<td>0.26</td>
<td>2.10 \times 10^{-4}</td>
</tr>
<tr>
<td>2</td>
<td>0.36</td>
<td>0.26</td>
<td>1.89 \times 10^{-3}</td>
</tr>
<tr>
<td>3</td>
<td>0.72</td>
<td>0.13</td>
<td>3.78 \times 10^{-3}</td>
</tr>
</tbody>
</table>

Show how these data can be used to deduce the rate expression for the reaction between A and B.

[3 marks]
The data in Table 2 were obtained in two experiments on the rate of the reaction between compounds C and D at a constant temperature.

Table 2

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial concentration of C / mol dm(^{-3})</th>
<th>Initial concentration of D / mol dm(^{-3})</th>
<th>Initial rate / mol dm(^{-3}) s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>(1.9 \times 10^{-2})</td>
<td>(3.5 \times 10^{-2})</td>
<td>(7.2 \times 10^{-4})</td>
</tr>
<tr>
<td>5</td>
<td>(3.6 \times 10^{-2})</td>
<td>(5.4 \times 10^{-2})</td>
<td>To be calculated</td>
</tr>
</tbody>
</table>

The rate equation for this reaction is

\[
rate = k[C]^2[D]
\]

01.2 Use the data from experiment 4 to calculate a value for the rate constant, \(k\), at this temperature. Deduce the units of \(k\).

[3 marks]

\[
k = \quad \text{Units} =
\]

01.3 Calculate a value for the initial rate in experiment 5.

[1 mark]

\[
\text{Initial rate} = \quad \text{mol dm}^{-3} \text{s}^{-1}
\]
The rate equation for a reaction is

\[ \text{rate} = k[E] \]

Explain qualitatively why doubling the temperature has a much greater effect on the rate of the reaction than doubling the concentration of \( E \).

[3 marks]

A slow reaction has a rate constant \( k = 6.51 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3 \) at 300 K.

Use the equation \( \ln k = \ln A - \frac{E_a}{RT} \) to calculate a value, in kJ mol\(^{-1}\), for the activation energy of this reaction.

The constant \( A = 2.57 \times 10^{10} \text{ mol}^{-1} \text{ dm}^3 \).
The gas constant \( R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1} \).

[2 marks]

Activation energy = ___________
Turn over for the next question
Butadiene dimerises according to the equation

\[ 2\text{C}_4\text{H}_6 \rightarrow \text{C}_8\text{H}_{12} \]

The kinetics of the dimerisation are studied and the graph of the concentration of a sample of butadiene is plotted against time. The graph is shown in Figure 1.

**Figure 1**

Draw a tangent to the curve when the concentration of butadiene is 0.0120 mol dm\(^{-3}\). [1 mark]
The initial rate of reaction in this experiment has the value $4.57 \times 10^{-6}$ mol dm$^{-3}$ s$^{-1}$.

Use this value, together with a rate obtained from your tangent, to justify that the order of the reaction is 2 with respect to butadiene.

[5 marks]
Isooctane ($\text{C}_8\text{H}_{18}$) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isoctane is shown in Figure 2.

Figure 2

Give the IUPAC name for isoctane.

Deduce the number of peaks in the $^{13}\text{C}$ NMR spectrum of isoctane.

Only one answer is allowed.

CORRECT METHOD ✔️  WRONG METHODS ✗  ✗  ✗  ✔️

If you want to change your answer you must cross out your original answer as shown. ✗

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. ✗
Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction. [1 mark]

How do the products of the reaction in Question 3.3 show that the reaction is an example of thermal cracking? [1 mark]

Deduce the number of monochloro isomers formed by isooctane. Draw the structure of the monochloro isomer that exists as a pair of optical isomers. [2 marks]

Number of monochloro isomers _____________________________

Structure

An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the skeletal formula of this monochloro compound. [1 mark]
A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes $^{35}\text{Cl}$ and $^{37}\text{Cl}$ in the ratio 1.5 : 1.0. Calculate the $M_r$ of this monochlorooctane.

$M_r = \underline{\phantom{00000}}$

Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds. One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass. Calculate the molecular formula of this compound.

Molecular formula = $\underline{\phantom{00000}}$
4 Alcohol \( \text{A} \) \((\text{CH}_3)_2\text{CHCH(OH)CH}_3\) undergoes reactions separately with acidified potassium dichromate(VI) and with concentrated sulfuric acid.

04.1 Deduce the IUPAC name for alcohol \( \text{A} \).

04.2 Draw the structure of the organic product, \( \text{B} \), formed when \( \text{A} \) is oxidised in the reaction with acidified potassium dichromate(VI).

04.3 Two isomeric alkenes, \( \text{C} \) and \( \text{D} \), are formed when \( \text{A} \) is dehydrated in the reaction with concentrated sulfuric acid.

Name the mechanism for this dehydration reaction.

04.4 Draw the structure of each isomer.

Isomer \( \text{C} \) Isomer \( \text{D} \)
04 . 5 Name the type of structural isomerism shown by C and D. [1 mark]

04 . 6 List alcohol A, product B and isomer C in order of increasing boiling point. [1 mark]

04 . 7 Draw the structure of the isomer of A that is not oxidised by acidified potassium dichromate(VI). [1 mark]

04 . 8 Draw the structure of the isomer of A that cannot be dehydrated to form an alkene by reaction with concentrated sulfuric acid. [1 mark]
Figure 3 shows a simplified representation of the arrangement of some amino acids in a portion of a protein structure in the form of an $\alpha$-helix.

Figure 3

05.1 Name the type of protein structure in Figure 3.

[1 mark]

05.2 Explain the origin of the interaction represented by the dotted lines in Figure 3.

[4 marks]
The tripeptide shown in Figure 4 is formed from the amino acids glycine, threonine and lysine.

Figure 4

H₂N—C—N—C—N—C—COOH

H      O      H      O      H      H

glycine  threonine  lysine

06.1 Draw a separate circle around each of the asymmetric carbon atoms in the tripeptide in Figure 4. [1 mark]

06.2 Draw the zwitterion of glycine. [1 mark]

06.3 Draw the structure of the species formed when glycine reacts with an excess of bromomethane. [1 mark]

06.4 Deduce the IUPAC name of threonine. [1 mark]

06.5 Draw the structure of the species formed by lysine at low pH. [1 mark]
Repeating units of two polymers, P and Q, are shown in Figure 5.

**Figure 5**

\[
\begin{align*}
P: & & H \quad CH_3 \\
  & & C - C \\
  & & CH_3 \quad Cl \\
Q: & & O \quad CH_3 \\
  & & C - C - O - C - C \\
  & & CH_3 \quad CH_3 \\
  & & H \quad CH_3 \\
\end{align*}
\]

07. 1 Draw the structure of the monomer used to form polymer P. Name the type of polymerisation involved. [2 marks]

Monomer

Type of polymerisation

07. 2 Draw the structures of two compounds that react together to form polymer Q. [2 marks]

Structure of compound 1

Structure of compound 2
Suggest an environmental advantage of polymer Q over polymer P. Justify your answer.

[3 marks]

Advantage ______________________________________

Justification ______________________________________

________________________________________________________________________

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Turn over for the next question
The anticancer drug cisplatin operates by reacting with the guanine in DNA.

Figure 6 shows a small part of a single strand of DNA. Some lone pairs are shown.

The DNA chain continues with bonds at X and Y.

State the name of the sugar molecule that is attached to the bond at X.]
Messenger RNA is synthesised in cells in order to transfer information from DNA. The bases in one strand of DNA pair up with the bases used to synthesise RNA.

Figure 7 shows two bases used in RNA.

![Figure 7 showing bases A and B](image)

Suggest which of the bases A and B forms a pair with guanine in Figure 6 when messenger RNA is synthesised. Explain how the base that you have chosen forms a base pair with guanine.

[4 marks]

Question 8 continues on the next page
Cisplatin works because one of the atoms on guanine can form a co-ordinate bond with platinum, replacing one of the ammonia or chloride ligands. Another atom on another guanine can also form a co-ordinate bond with the same platinum by replacing another ligand.

On Figure 6, draw a ring round an atom in guanine that is likely to bond to platinum.

[1 mark]

An adverse effect of cisplatin is that it also prevents normal healthy cells from replicating.

Suggest one way in which cisplatin can be administered so that this side effect is minimised.

[1 mark]
1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in Figure 8.

![Figure 8](image)

A suitable reagent for step 1 is CH₃COCl.

Name and draw a mechanism for the reaction in step 1. [5 marks]

Name of mechanism _____________________________

Mechanism

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*Barcode*
The product of step 1 was purified by recrystallisation as follows.

The crude product was dissolved in the **minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature**. The crystals formed were filtered off using a Buchner funnel and a clean cork was used to compress the crystals in the funnel. A little cold water was then poured through the crystals.

After a few minutes, the crystals were removed from the funnel and weighed. A small sample was then used to find the melting point.

Give reasons for each of the following practical steps. [4 marks]

The minimum quantity of hot water was used

The flask was cooled to room temperature before the crystals were filtered off

The crystals were compressed in the funnel

A little cold water was poured through the crystals

Question 9 continues on the next page
The melting point of the sample in Question 9.2 was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.

[2 marks]

Figure 8 is repeated here to help you answer the following questions.
In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step 1.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures. 

\[
\text{Percentage yield} = \frac{\text{Obtained product}}{\text{Initial material}} \times 100 \%
\]

A reagent for step 2 is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step 2.

Name a mechanism for the reaction in step 2.

Suggest the type of reaction occurring in step 3.

Identify the reagents used in step 4.
The infrared spectrum (Figure 9) and the $^1$H NMR spectrum (Figure 10) of compound R with molecular formula C$_6$H$_{14}$O are shown.

**Figure 9**

**Figure 10**
The relative integration values for the NMR peaks are shown on Figure 10.

Deduce the structure of compound R by analysing Figure 9 and Figure 10. Explain each stage in your deductions.

Use Table A and Table B on the Data Sheet.

[8 marks]
Butanone is reduced in a two-step reaction using NaBH₄ followed by dilute hydrochloric acid.

Write an overall equation for the reduction of butanone using [H] to represent the reductant.

By considering the mechanism of the reaction, explain why the product has no effect on plane polarised light.
12. But-1-ene reacts with a reagent of the form HY to form a saturated compound.

12.1 Suggest a reagent of the form HY which reacts with but-1-ene. [1 mark]

____________________________________

12.2 Name and draw a mechanism for the reaction in Question 12.1. [5 marks]

Name of mechanism __________________________________________________________

Mechanism

12.3 Explain how three isomeric products are formed when HY reacts with but-1-ene. [3 marks]

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END OF QUESTIONS
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