Oxford Cambridge and RSA

Tuesday 11 June 2019 – Afternoon

A Level Chemistry B (Salters)

H433/02 Scientific literacy in chemistry

Time allowed: 2 hours 15 minutes

You must have:
- the Insert (inserted)
- the Data Sheet for Chemistry B (Salters) (sent with general stationery)

You may use:
- a scientific or graphical calculator

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- The Insert will be found inside this document.
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

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Answer **all** the questions.

1 Twaron™ is a polymer used to make body armour.

The polymer strands are made using the reaction in **Fig. 1.1**.

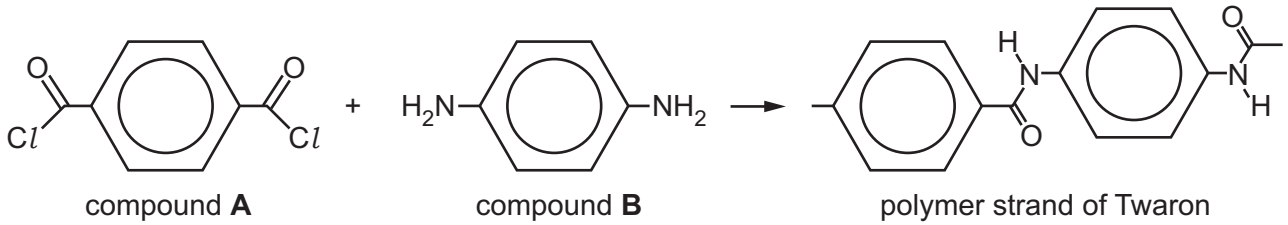

Fig. 1.1

(a) Name the **functional groups** in compounds **A** and **B**.

A .....

B .....

[2]

(b) Suggest the O=$\widehat{C}$–C*l* bond angle in compound **A**.

Explain your answer.

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..... **[3]**

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(c) Compound **A** can be made by the reaction in **Fig. 1.2**.

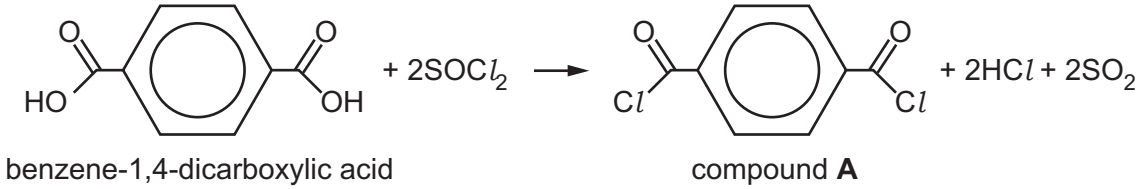

Fig. 1.2

Calculate the mass of compound **A** that can be made from 32 g of benzene-1,4-dicarboxylic acid if the yield is 67%.

Give your answer to the nearest whole number.

mass of compound **A** = ... g **[2]**

(d) A synthetic route for making compound **B** is shown in **Fig. 1.3**.

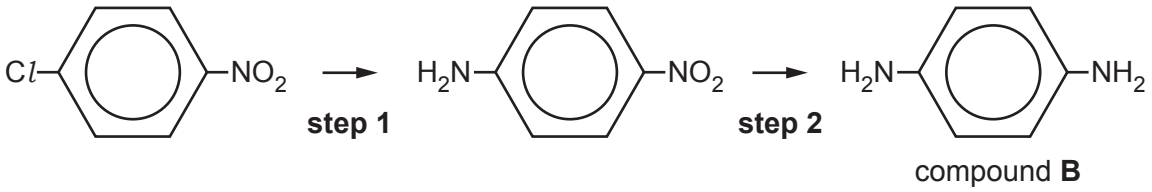

Fig. 1.3

Use your chemical knowledge and the Data Sheet to suggest possible reagents for **steps 1** and **2**.

Step 1 .....

Step 2 .....
[2]

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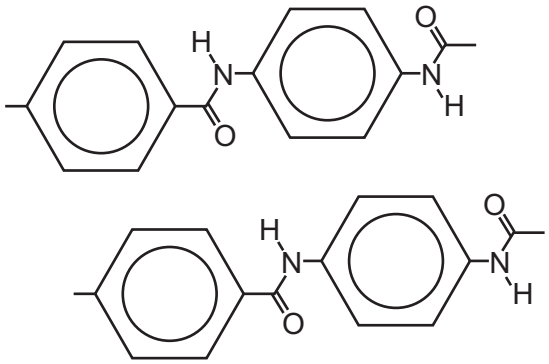
(e) The polymer strands link together by intermolecular bonds when they are spun to form Twaron. This gives the fabric its tough quality.

(i) Name the strongest intermolecular bonds that can form between the chains.

..... **[1]**

(ii) Mark the positions of the intermolecular bonds by drawing dotted lines on the diagram below.



[1]

(f) A Twaron polymer strand is hydrolysed.

(i) State the conditions that could be used to hydrolyse the polymer.

..... **[1]**

(ii) Draw the formulae of the **two** organic products of hydrolysis in the boxes.

[2]

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2 Strontium carbonate is used in fireworks to colour the flames red.

(a) The red colour comes from lines of specific frequency in the atomic emission spectrum of strontium.

Explain how these lines are formed.

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..... **[3]**

(b) Strontium carbonate decomposes to give strontium oxide when heated.

$SrCO_3 \rightarrow SrO + CO_2$

(i) 12.0 g of $SrCO_3$ are heated.

Calculate the volume of CO_2 (in cm^3) that would be collected at 290 K and 155 kPa.

Give your answer to an **appropriate** number of significant figures.

volume of CO_2 = ... cm^3 **[4]**

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(ii) A student says 'Strontium ions are larger than calcium ions, so the attraction to carbonate ions is weaker. This means that strontium carbonate has a lower thermal stability than calcium carbonate.'

Discuss the student's statement, giving the correct chemistry where necessary.

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..... **[4]**

(c) A sample of strontium metal has the isotopic composition shown in the table.

Mass number	84	86	87	88
Abundance / %	0.56	9.86	7.00	82.58

(i) How many neutrons are there in an atom of ^{84}Sr?

number of neutrons = ... **[1]**

(ii) Use the data to calculate the relative atomic mass of the strontium sample.

Give your answer to **2** decimal places.

relative atomic mass = ... **[2]**

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(d)* Strontium oxide reacts with water to form strontium hydroxide, $Sr(OH)_2$.

The solubility of strontium hydroxide in water at room temperature is around $10\,g\,dm^{-3}$.

A student is given a saturated solution of strontium hydroxide, normal titration equipment and a variety of different concentrations of hydrochloric acid.

The student wishes to find an accurate value for the concentration of the solution in $mol\,dm^{-3}$.

Describe in full a suitable procedure and indicate how the result would be calculated. **[6]**

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(e) **(i)** Write the equation for the equilibrium that occurs between solid strontium hydroxide and its ions in solution.

Use your equation to write the expression for the solubility product of strontium hydroxide.

Equation with state symbols:

K_{sp} = **[2]**

(ii) At 0 °C, the solubility of strontium hydroxide in water is 3.4×10^{-2} mol dm^{-3}.

Calculate the solubility product of strontium hydroxide at this temperature.

Give the units in your answer.

solubility product = ... units .....**[3]**

(iii) Explain how the solubility of strontium hydroxide in aqueous NaOH at 0 °C compares with 3.4×10^{-2} mol dm^{-3}.

Use the idea of solubility product in your answer.

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..... **[2]**

(f) The melting point of strontium is higher than the melting point of rubidium.

(i) To which block of the Periodic Table do these elements belong?

..... **[1]**

(ii) Explain the difference in melting point.

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..... **[2]**

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3 Chlorine is made by electrolysing sodium chloride solution.

Sodium chlorate(V) is made by letting the chlorine react with the hydroxide ions that are also produced.

(a) When chlorine reacts with hot hydroxide ions, part of the chlorine is oxidised to chlorate(V) and the rest of the chlorine is reduced to chloride.

Use oxidation states to balance the equation for the reaction.

$$.....Cl_2 + ...OH^- \rightarrow .....ClO_3^- + ...Cl^- + ...H_2O$$ **[2]**

(b) ClO_2 can be made by reacting ClO_3^- with concentrated hydrochloric acid.

$$2ClO_3^- + 4H^+ + 2Cl^- \rightleftharpoons 2ClO_2 + 2H_2O + Cl_2$$ **Equation 3.1**

ClO_2 is used for water purification and for bleaching the pulp used to make paper.

Table 3.1 shows some electrode potential data.

Half-reaction	$E^{\ominus}$/V
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$ClO_3^-(aq) + 2H^+(aq) + e^- \rightleftharpoons ClO_2(aq) + H_2O(l)$	+1.15
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

Table 3.1

(i) The forward reaction in **equation 3.1** does **not** occur under standard conditions.

Use data from **Table 3.1** to explain why.

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..... **[2]**

(ii) Suggest why the forward reaction in **equation 3.1 does** occur in the presence of concentrated hydrochloric acid.

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..... **[2]**

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(c) A student investigates the reactions of some halogen compounds using the data in **Table 3.1**.

Half-reaction	$E^{\ominus}$/V
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$ClO_3^-(aq) + 2H^+(aq) + e^- \rightleftharpoons ClO_2(aq) + H_2O(l)$	+1.15
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

Table 3.1

(i) The student uses a $Cu^{2+}(aq)/Cu(s)$ half-cell to confirm the $E^{\ominus}$ of a $Cl_2(aq)/Cl^-(aq)$ half-cell.

Complete and label the diagram of the apparatus the student would set up.

Show state symbols.

Indicate how standard conditions are achieved.

[4]

(ii) Give the value of $E^{\ominus}_{cell}$ for the cell in **(c)(i)**.

$E^{\ominus}_{cell}$ = ... V **[1]**

(iii) State where the electrons move and which way they are moving when the cell delivers a current.

.....

..... **[1]**

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(iv) A standard hydrogen electrode is used to measure $E^{\ominus}$ values, such as those in **Table 3.1**.

Give the half-cell reaction that occurs at a hydrogen electrode.

Show state symbols.

[1]

(v) The E value for the copper electrode at 298 K varies with the concentration of copper ions. The equation for this is shown below.

$E = E^{\ominus} + 0.0128\ ln\ [Cu^{2+}]$

Calculate the E value for a copper electrode where $[Cu^{2+}] = 0.010\ mol\ dm^{-3}$.

E = ... V **[2]**

(d) From data in **Table 3.1**, the student knows that chlorine reacts with iodide ions in aqueous solution.

(i) Write an equation for the reaction that occurs.

[1]

(ii) **Name** the reducing agent in your reaction in **(d)(i)**.

..... **[1]**

(iii) What will be **seen** when the reaction in **(d)(i)** occurs?

..... **[1]**

(iv) Explain, in terms of electrons, why chlorine is more reactive than iodine.

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..... **[1]**

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(e) The student uses a simple apparatus to prepare a test-tube full of hydrogen chloride gas in the laboratory.

Draw a diagram of an apparatus the student could use, labelling the reactants.

[2]

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4 Dinitrogen pentoxide, N_2O_5 is an oxide of nitrogen that is formed in the stratosphere by reactions such as those shown below.

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$

$$NO_3 + NO_2 \rightleftharpoons N_2O_5$$

The dinitrogen pentoxide acts as a 'sink' for NO_2, stopping it breaking down ozone.

(a) A student says that oxides of nitrogen catalyse the breakdown of ozone in the stratosphere by the reactions shown below.

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$

$$O_3 + NO_3 \rightarrow NO_2 + 2O_2$$

Discuss the student's choice of reactions, giving the correct chemistry if necessary.

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..... **[2]**

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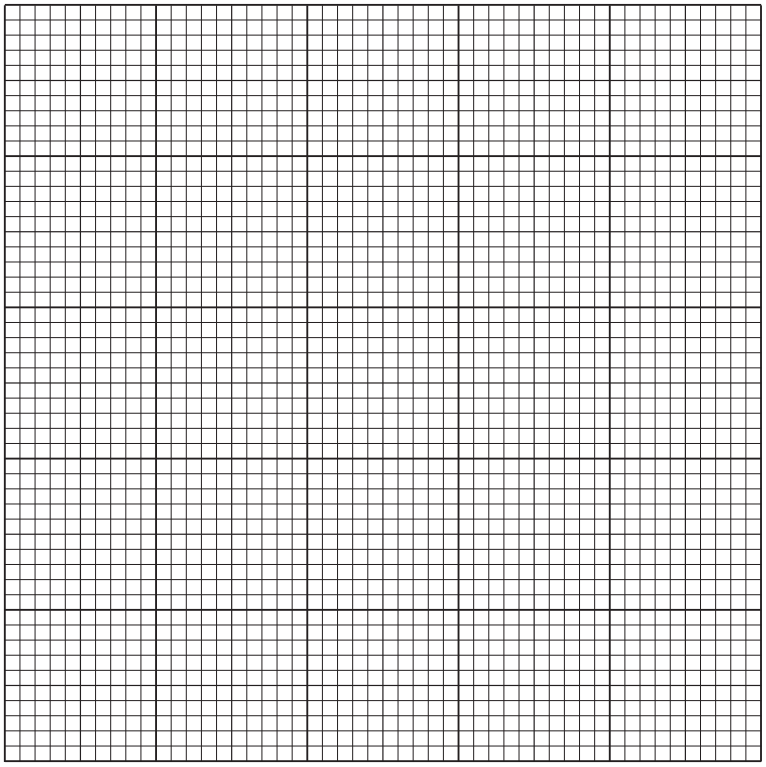
(b) In the troposphere, dinitrogen pentoxide decomposes as shown below.

$2N_2O_5 \rightarrow 4NO_2 + O_2$ **Equation 4.1**

The table shows how the concentration of $2N_2O_5$ varies with time at 315 K.

Time / s	**$[N_2O_5]$ / mol dm^{-3}**
0	0.330
1000	0.210
2000	0.124
3000	0.078
4000	0.048

(i) Use the data in the table to plot a graph to determine the half-life for the reaction. Label the axes.



half-life = ... s **[4]**

(ii) How does the graph show that the reaction in **equation 4.1** is first order with respect to N_2O_5?

Draw construction lines on the graph to explain your answer.

..... **[1]**

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(c) The gradient of the graph at 1000 s is 9.8×10^{-5} mol dm^{-3} s^{-1}.

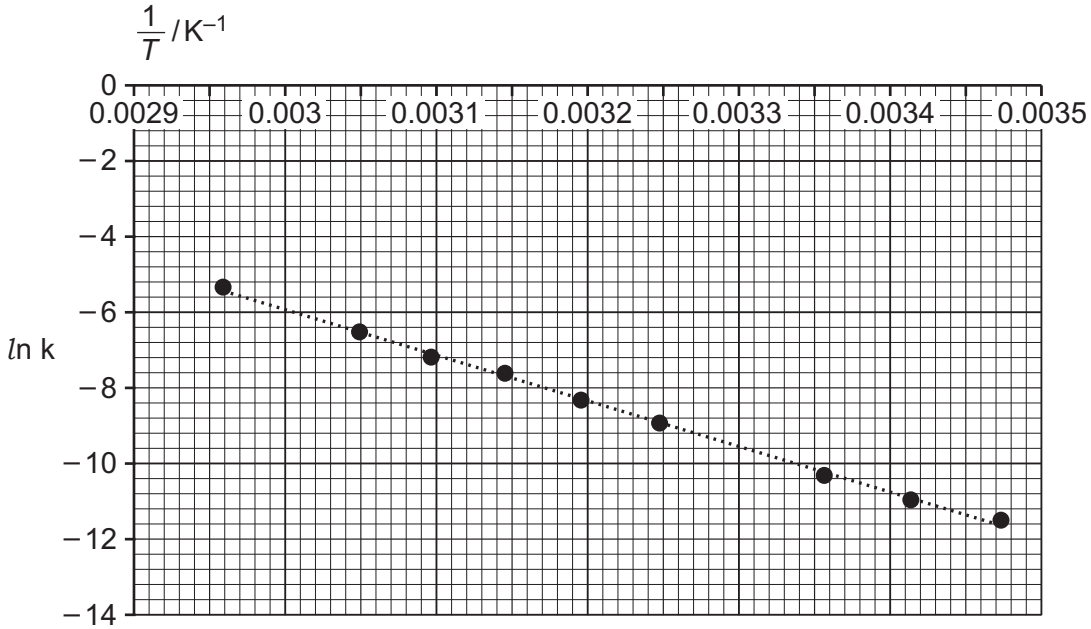
Work out the rate constant for the reaction in **equation 4.1** at 315 K.

Give the units in your answer.

rate constant = ... units ..... **[2]**

(d) The reaction in **equation 4.1** was repeated with a fixed concentration of N_2O_5 at different temperatures.

A graph of $\ln$ k against $\frac{1}{T}$ for the reaction in **equation 4.1** is given below.



Use the graph to work out a value for the activation enthalpy (in kJ mol^{-1}) for the reaction.

E_a = ... kJ mol^{-1} **[3]**

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$2N_2O_5 \rightarrow 4NO_2 + O_2$ **Equation 4.1**

(e) A student suggests the following mechanism for the reaction in **equation 4.1**.
The reaction is first order with respect to N_2O_5.

$N_2O_5 \rightarrow NO_2 + NO_3$ **step 1**
$NO_3 \rightarrow O_2 + NO$ **step 2**
$NO + N_2O_5 \rightarrow 3NO_2$ **step 3**

Show that this is a possible mechanism.

Consider which step(s) could be rate-determining.

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..... **[3]**

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5 This question refers to the Advance Notice Article 'Clearing the air around smoke formation' that is included as an insert in this paper.

(a) The enthalpy change of combustion of acetylene, C_2H_2, can be calculated using enthalpy changes of formation.

Draw the Hess cycle that shows this, giving formulae and state symbols.

Label the enthalpy changes of formation and show how they can be combined to give the enthalpy change of combustion.

You do not need to give ΔH values.

[3]

(b) The Article refers to a 'back-of-the-envelope' calculation. This shows that the number of acetylene molecules combusting is approximately 1.4 times greater than the number of ethane molecules in the same volume of air/fuel mixture.

Use a similar calculation for **propane**.

Calculate how many more acetylene molecules combust in air in a given volume of air/fuel mixture compared with propane.

(Assume air contains 20% oxygen by volume.)

Number of acetylene molecules combusting is approximately ..... times greater than the number of propane molecules in the same volume. **[4]**

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(c) In an sp^2 hybrid carbon atom, one s orbital joins with two p orbitals to form three 'hybrid' sp^2 orbitals of the same energy. This leaves one other p orbital of a similar energy containing one electron.

(i) Explain why the remaining p orbital contains one electron.

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..... **[2]**

(ii) State what happens to these single p electrons in the structures of ethene and naphthalene.

ethene .....

naphthalene .....
[2]

(d) **Fig. 2** in the Article shows the formation of naphthalene from benzene.

Suggest the first step in the formation of a larger PAH from naphthalene.

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..... **[1]**

(e) The equation $C_4H_{10} + M \rightarrow C_3H_7 + CH_3 + M$, is given in the Article. M is a molecule.

(i) Classify this reaction as *initiation*, *propagation* or *termination* with a reason.

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..... **[1]**

(ii) Suggest a reason for the involvement of the molecule M.

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..... **[1]**

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(f)* Oxygen is involved in the formation of soot in the flame of a burning hydrocarbon.

Discuss the role of oxygen in controlling the flame temperature, causing small molecule reactions and providing competing routes.

Illustrate your answer with equations where appropriate. **[6]**

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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