Oxford Cambridge and RSA

Monday 16 June 2025 – Morning

A Level Chemistry B (Salters)

H433/02 Scientific literacy in chemistry

Time allowed: 2 hours 15 minutes

You must have:
- a clean copy of the Advance Notice Article (inside this document)
- the Data Sheet for Chemistry B

You can use:
- a scientific or graphical calculator
- an HB pencil

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

Centre number						Candidate number				

First name(s) ____________________

Last name ____________________

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined page at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

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

ADVICE
- Read each question carefully before you start your answer.

1 This question is about reactions of haloalkanes.

(a) CH_3Cl is made by plants that grow on marshes.

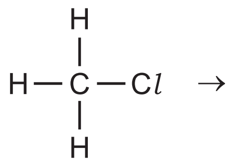
If CH_3Cl reaches the stratosphere, electromagnetic radiation causes it to undergo homolytic fission forming chlorine radicals.

(i) Give the systematic name of CH_3Cl.

.... **[1]**

(ii) Draw 'half curly arrows' to show the mechanism of the homolytic fission of CH_3Cl.

Show the products of the reaction.



[2]

(iii) Which **type** of electromagnetic radiation causes this homolytic fission to occur in the stratosphere?

.... **[1]**

(iv) The bond energy of the C–Cl bond is $346\,kJ\,mol^{-1}$.

Calculate the **wavelength** (in m) of radiation which breaks this bond.

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

Wavelength = ... m **[5]**

(v) Chlorine radicals catalyse the breakdown of ozone in the stratosphere.

Write equations to show how this occurs and give the overall equation.

Overall equation:

[2]

(vi) Why is the breakdown of ozone in the stratosphere harmful to humans?

....

....

.... **[2]**

(b) CH_3Cl reacts with ammonia to give an amine salt.

$CH_3Cl + NH_3 \rightarrow CH_3NH_3Cl$ **Equation 1.1**

Ammonia is acting as a nucleophile here.

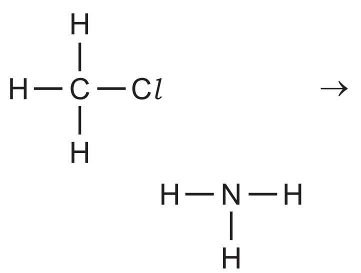
(i) Explain what is meant by the term **nucleophile**.

....

.... **[1]**

(ii) Show the mechanism of **Equation 1.1**.

Use curly arrows and show relevant lone pairs and the ionic products.



[2]

(iii) The product of **Equation 1.1** is a salt of CH_3NH_2.

Give the systematic name for CH_3NH_2.

.... **[1]**

(c) The reaction between a haloalkane and hydroxide ions is a nucleophilic substitution reaction.

A student reacts 1-chlorobutane, 1-bromobutane and 1-iodobutane separately with aqueous sodium hydroxide.

Which will react fastest and why?

....

....

.... **[2]**

2 Some students study the nitrogen compounds in the soil.

(a) How many neutrons are in an atom of ^{14}N?

.... **[1]**

(b) The students make ammonia from a fertiliser containing NH_4^+ ions.

Identify the reagent that they use.

.... **[1]**

(c) The students add an aqueous solution of ammonia to a solution of $FeSO_4$.
A precipitate forms.

Give the colour of the precipitate and write an **ionic** equation for its formation.

Include state symbols.

Colour: ....

Ionic equation:

[3]

(d) The students read that ammonium ions are oxidised to NO_2^- by bacteria in the soil.

(i) Give the systematic name of NO_2^-.

.... **[1]**

(ii) The students add acid to $NaNO_2(s)$ in a test tube.
A colourless gas **A** (with nitrogen in the +2 oxidation state) and NO_3^- ions are produced.

Gas **A** turns to a brown gas **B** at the top of the test tube.

Suggest the **formula** of the brown gas **B**.

Suggest an **ionic** equation for the formation of **gas A** from acidified NO_2^- ions.

Formula of brown gas **B**: ....

Ionic equation:

[3]

(e) The students read that a sample of $N_2O(g)$ can be prepared by heating a mixture of the solids $NaNO_3$ and $(NH_4)_2SO_4$.

$2NaNO_3(s) + (NH_4)_2SO_4(s) \rightarrow 2N_2O(g) + 4H_2O(l) + Na_2SO_4(aq)$ **Equation 2.1**

(i) The students want to test **Equation 2.1** by measuring the volume of **dry** N_2O produced by heating $(NH_4)_2SO_4$ with $NaNO_3$.

Draw a labelled diagram of an apparatus they could use.

[4]

(ii) The students heat 0.20 g of $(NH_4)_2SO_4$ with excess $NaNO_3$.

Calculate the volume of N_2O (in cm^3) that would be formed at 20 °C and 105 kPa.

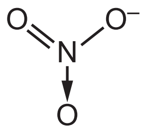
Volume = ... cm^3 **[4]**

(f) Another oxide of nitrogen contains 37% nitrogen by mass.

Calculate the formula of the oxide.

Formula = ... **[2]**

(g)* An NO_3^- ion can be represented as shown:



A student says that NH_3 and NO_3^- have the same shape and bond angles.

Discuss this, drawing 'dot-and-cross' diagrams and giving chemical explanations for the shapes and bond angles.

'Dot-and-cross' diagrams

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.... **[6]**

Extra answer space if required.

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3 Some scientists investigate the reaction of nitrogen monoxide with chlorine.

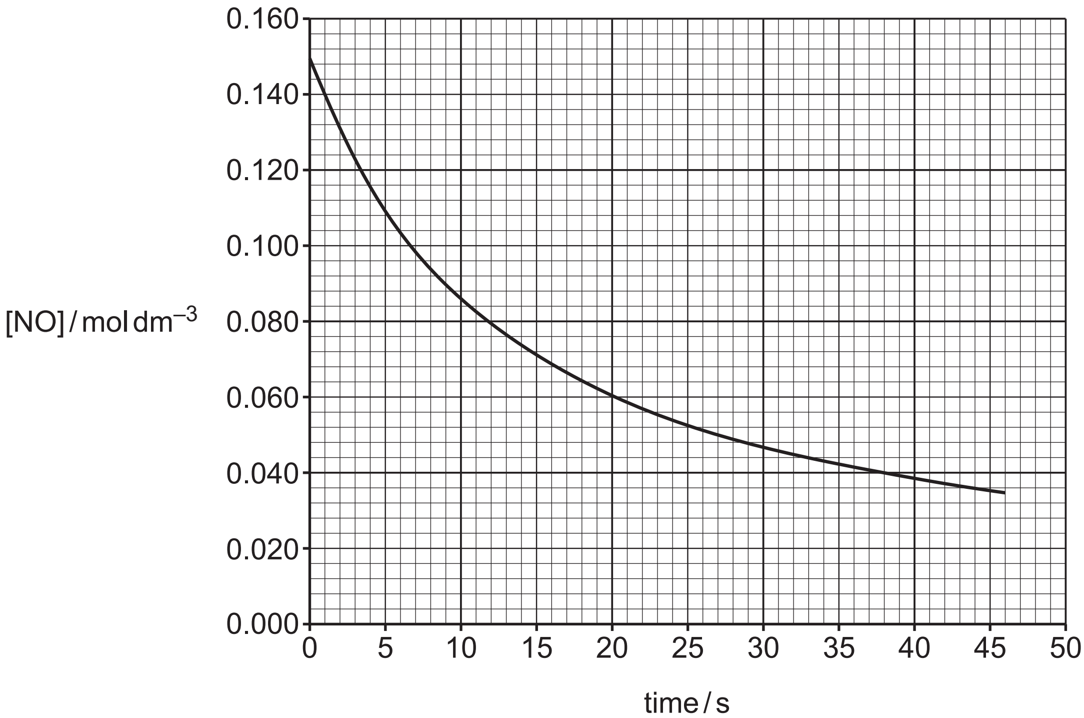
The reaction is:

$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$ **Equation 3.1**

The scientists wish to determine the order of the reaction with respect to NO.

They start their experiment by mixing a known concentration of NO with a large excess of Cl_2.

They then measure the concentration of NO over time and plot a graph of [NO] against time.



(a) Explain why a large excess of Cl_2 is required.

....

.... **[1]**

(b) Use the graph to work out the **initial** rate of the reaction in mol dm^{-3} s^{-1}.

Show your working on the graph.

Initial rate = ... mol dm^{-3} s^{-1} **[2]**

(c) The scientists measure the initial rates of reaction for other NO concentrations.

Their results are shown in **Table 3.1**.

Table 3.1

[NO] / mol dm^{-3}	**[NO]^2 / (mol dm^{-3})^2**	**Initial rate / mol dm^{-3} s^{-1}**
8.59×10^{-2}	7.38×10^{-3}	3.28×10^{-3}
6.10×10^{-2}	3.72×10^{-3}	1.65×10^{-3}
4.75×10^{-2}	....	1.00×10^{-3}
3.89×10^{-2}	1.51×10^{-3}	0.67×10^{-3}

The scientists plot initial rate against [NO] and discover this does **not** give a straight line.

(i) What can the scientists conclude from this?

....

.... **[1]**

(ii) Fill in the missing value in **Table 3.1**. **[1]**

(iii) Plot a graph of initial rate against $[NO]^2$.

Use the data in **Table 3.1**.

Include the origin.

Draw the line of best fit.

[4]

(iv) Explain why the graph shows that the reaction is second order with respect to NO.

....

.... **[1]**

(d) The scientists find that the reaction is first order with respect to Cl_2.

(i) Complete the rate equation for the reaction.

Rate = k ×

[1]

(ii) Give the units of the rate constant, k.

.... **[1]**

(iii) Explain why the value of the rate constant **cannot** be calculated from data in this question.

....

.... **[1]**

(iv) The scientists conclude that a possible mechanism is as shown below, with **step 2** being rate-determining.

$NO + Cl_2 \rightarrow NOCl_2$ **Step 1**

$NOCl_2 + NO \rightarrow 2NOCl$ **Step 2**

Give the meaning of rate-determining step and explain why the scientists conclude that **Step 2** is the rate-determining step.

Meaning ....

....

Explanation ....

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....

....

[3]

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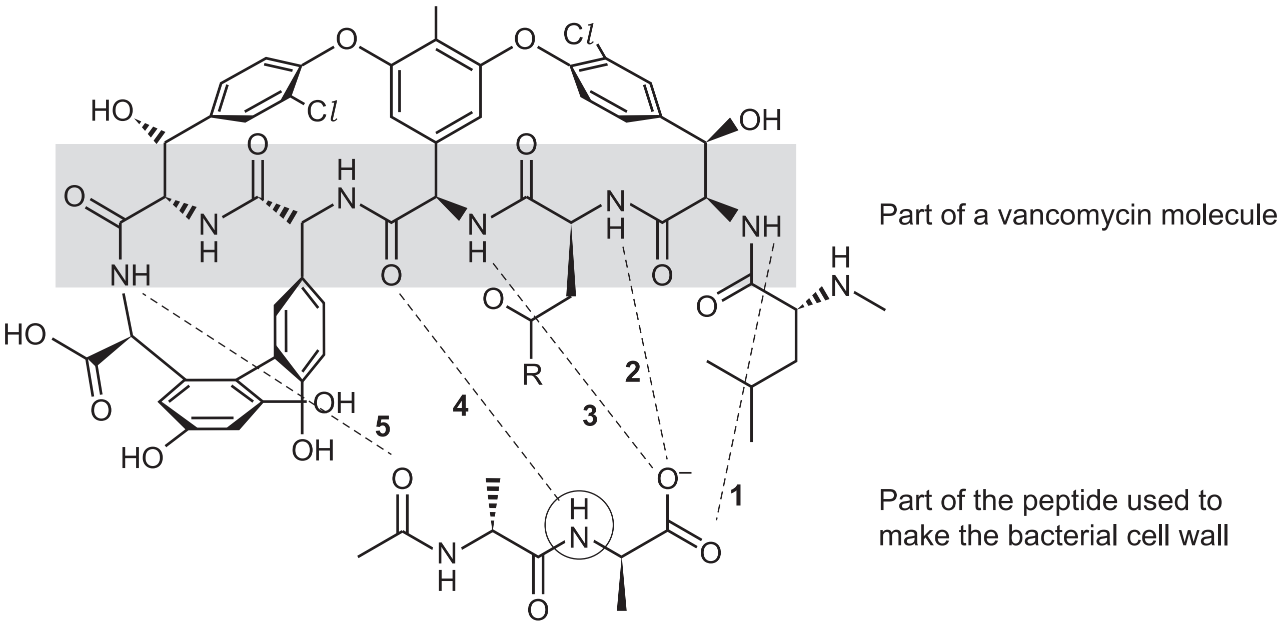
4 This question is about molecular recognition.

(a) Vancomycin is an antibacterial drug. It binds with peptides that bacteria use to make their cell walls. When the vancomycin binds, the process of making cell walls is disrupted, so the bacteria cannot grow.

Fig. 4.1 shows part of a vancomycin molecule bonded to part of the peptide.

Fig. 4.1



(i) Vancomycin has a polypeptide chain. The area shaded grey represents the primary structure. In order for vancomycin to function, the primary structure must be held in a definite shape. This enables intermolecular bonds **1**, **2**, **3**, **4** and **5** to form.

Describe how the primary structure is held in this definite shape in vancomycin.

....

.... **[1]**

(ii) The part of the **peptide** shown at the bottom of **Fig. 4.1** is made from a repeat of the same amino acid.

Give the structure of this amino acid.

[1]

(iii) Name the **type** of intermolecular bond shown by the numbers **1**, **4** and **5** and suggest why these bonds are weaker than bonds **2** and **3**, even though they are of similar length.

....

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....

.... **[3]**

(iv) In the peptides from some bacteria, the circled NH in **Fig. 4.1** is replaced by an oxygen atom, O. These bacteria are resistant to vancomycin.

Suggest why vancomycin has less effect on these bacteria.

....

....

....

.... **[2]**

(b) The binding of vancomycin is an example of molecular recognition.

Many medicines have part of their molecule that interacts in this way.

Name this part of a medicine molecule.

.... **[1]**

(c) Molecular recognition occurs in the formation of proteins from messenger RNA.

Explain this process.

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.... **[3]**

(d) Enzymes have a three-dimensional region that bonds with the substrate.

Name this region.

.... **[1]**

(e) Dyes attach themselves to fibres by a variety of bonds.

(i) Acid dyes have $–SO_3^-$ groups. These groups form ionic bonds with nylon fabrics under acid conditions.

Explain how this occurs.

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....

.... **[2]**

(ii) Some dyes form instantaneous dipole–induced dipole bonds with certain fabrics.

Explain how instantaneous dipole–induced dipole bonds are formed.

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.... **[3]**

5 This question refers to the Advance Notice Article Battery Tech Report: ‘Lithium-Ion vs Vanadium Redox Flow Batteries (VRFB)’ that is included as an Insert to this paper.

(a)* Explain why lithium has only one oxidation state in its compounds while vanadium has several.

Give electron configurations of atoms and several ions in your answer.

.... **[6]**

Extra answer space if required.

....

(b) **Table 5.1** shows some redox potentials.

Table 5.1

Redox system	$E^{\ominus}$ **/ V**
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00

(i) When the VRFB is delivering a current, V(V) is reduced to V(IV) and V(II) is oxidised to V(III).

Write the ionic equation and give the $E^{\ominus}_{cell}$ for the overall reaction that occurs.

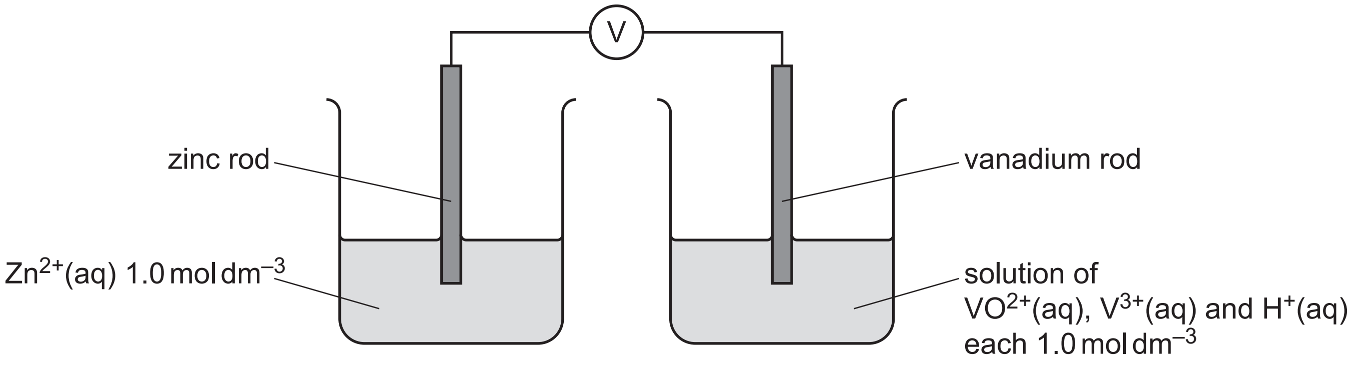
Include state symbols.

Ionic equation:

$E^{\ominus}_{cell}$ .... V **[2]**

(ii) A student sets up a cell to measure the $E^{\ominus}_{cell}$ for VO^{2+}/V^{3+} against Zn^{2+}/Zn at 298 K.

Here is a diagram of the student's cell.



The student has made **two** mistakes in setting up the cell.

Describe these mistakes **and** how they should be corrected:

Mistake 1 ....

....

Mistake 2 ....

....
[2]

(iii) A student has powdered samples of the metals (silver, tin and zinc) shown in **Table 5.1**, and an acidic solution of $VO_2^+(aq)$.

The student wants to obtain a solution containing V^{3+} ions.

Explain why the student would use tin rather than silver or zinc.

Write the overall equation for the student's reaction.

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Overall equation:

[4]

(c) The two types of battery have properties that are suited to different uses.

(i) From the article, give **two advantages** of Li-ion batteries over VRFBs as **batteries for electric vehicles**.

Advantage 1 ....

....

Advantage 2 ....

....
[2]

(ii) From the article, give **two advantages** of VRFBs over Li-ion batteries for large-scale use in **storing energy from an array of solar cells**.

Advantage 1 ....

....

Advantage 2 ....

....
[2]

(d) Both types of battery have a separator in the middle.

Give the formulae of the particles that pass through the separators in each battery when they are in use.

Li-ion battery ....

VRFB ....
[1]

(e) Solutions of vanadium compounds are coloured.

(i) Explain why they are coloured, selecting terms from the following list as required:

absorption **complementary** **emission** **transmission**

....

....

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....

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.... **[2]**

(ii) Explain why the colours are different.

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.... **[2]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use this lined page. You must write the question numbers clearly in the margin.