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Chemistry
Standard level
Paper 2

19 May 2025

Zone A morning | **Zone B** morning | **Zone C** morning

Candidate session number

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1 hour 30 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



Answer **all** questions. Answers must be written within the answer boxes provided.

1. Hydrogen cyanide, HCN, is a very toxic compound.

(a) Pure HCN is a volatile liquid, boiling at 26 °C.

(i) Draw the Lewis formula of the HCN molecule.

[1]

(ii) State and explain the molecular geometry of HCN.

[2]

Molecular geometry:

Explanation:

.....

.....

(iii) HCN is a polar molecule. Deduce which atom carries a partial positive charge and which carries a partial negative charge.

[1]

Partial positive charge:

Partial negative charge:

(iv) Explain why nitrogen gas, N₂, has a much lower boiling point than HCN.

[2]

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(This question continues on the following page)



(Question 1 continued)

(b) HCN acts as a weak acid in aqueous solution.

(i) Write an equation to show this behaviour. [1]

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.....

(ii) Outline **two** ways in which you could determine that a solution was 0.1 mol dm^{-3} HCN rather than 0.1 mol dm^{-3} HCl. [2]

Method 1:

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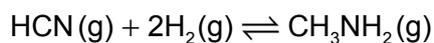
Method 2:

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(iii) Determine the pH of $0.100 \text{ mol dm}^{-3}$ HCN(aq) if the $[\text{H}^+]$ is $7.00 \times 10^{-6} \text{ mol dm}^{-3}$. [1]

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(c) Hydrogen cyanide reacts with hydrogen according to the equilibrium:



(i) Write the expression for the equilibrium constant, K . [1]

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(ii) Determine the oxidation states that indicate that carbon is reduced in this reaction. [1]

Initial oxidation state:

Final oxidation state:



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will not be marked.



2. Thallium is a heavy metal in group 13 of the periodic table.

(a) 30% of thallium atoms contain 122 neutrons and the remainder 124 neutrons.

(i) Deduce the nuclear symbol of the isotope of thallium containing 122 neutrons.
Use section 7 of the data booklet. [1]

	Tl

(ii) Calculate, to **two** decimal places, the relative atomic mass of thallium. [2]

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(iii) Explain why, in terms of nuclear charge and the shielding of the valence electrons, the first ionization energy of thallium is lower than that of lead. [2]

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(Question 2 continued)

(b) Thallium(I) sulfate has the formula Tl_2SO_4 .

(i) The compound contains both ionic and covalent bonds. State which particles are joined by covalent bonds and which are joined by ionic bonds. [2]

Covalent bond between: and

Ionic bond between: and

(ii) Contrast covalent and ionic bonds based on the valence electron interactions. [1]

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(iii) Write an equation for producing thallium(I) sulfate solution by reacting solid thallium(I) hydroxide with sulfuric acid. [2]

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(iv) Calculate the volume of 2.00 mol dm^{-3} sulfuric acid required to react completely with 10.0g of thallium(I) hydroxide. [3]

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(Question 2 continued)

- (v) Predict whether or not thallium(I) hydroxide is amphoteric, considering the position of thallium in the periodic table.

[1]

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- (vi) Discuss how the relative reactivity of copper and thallium could be established using the metals and aqueous solutions of their sulfates.

[2]

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3. Phosgene (carbonyl dichloride, Cl_2CO) is an important industrial intermediate.

(a) Phosgene may be formed by the free-radical reaction between carbon monoxide, CO , and chlorine, Cl_2 , which is initiated by UV light.

(i) Write an equation for the initiation reaction. [1]

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(ii) State the type of bond fission that is occurring. [1]

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(iii) Determine the enthalpy change for the reaction between carbon monoxide and chlorine from bond enthalpies. Use section 12 of the data booklet. [3]

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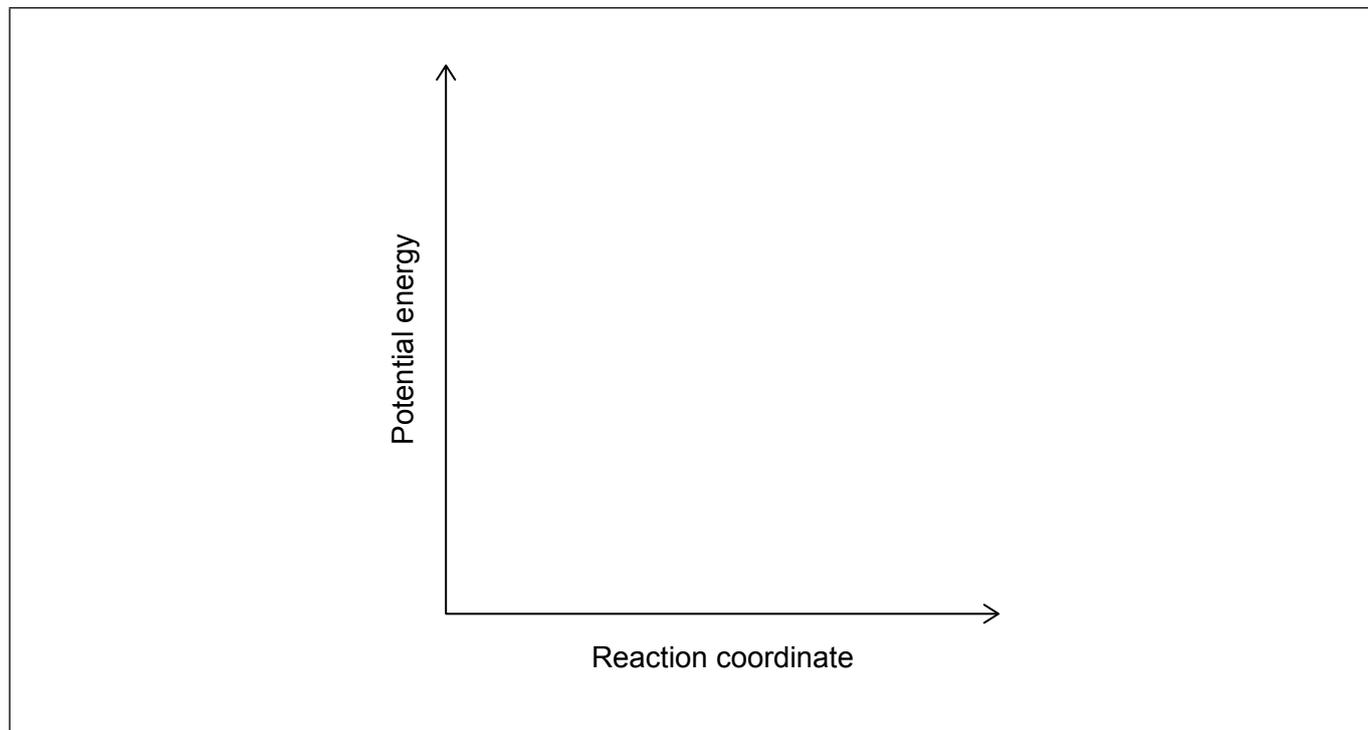
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(Question 3 continued)

- (iv) Sketch an energy profile for this reaction and label the "Reactants", "Products" and " ΔH ".

[2]

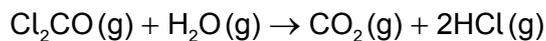


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(Question 3 continued)

(b) Phosgene gradually decomposes in the environment according to the equation:



(i) Suggest how the rate of this reaction could be followed at constant temperature. [1]

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(ii) Outline why some collisions between reactant molecules do not result in a reaction occurring. [2]

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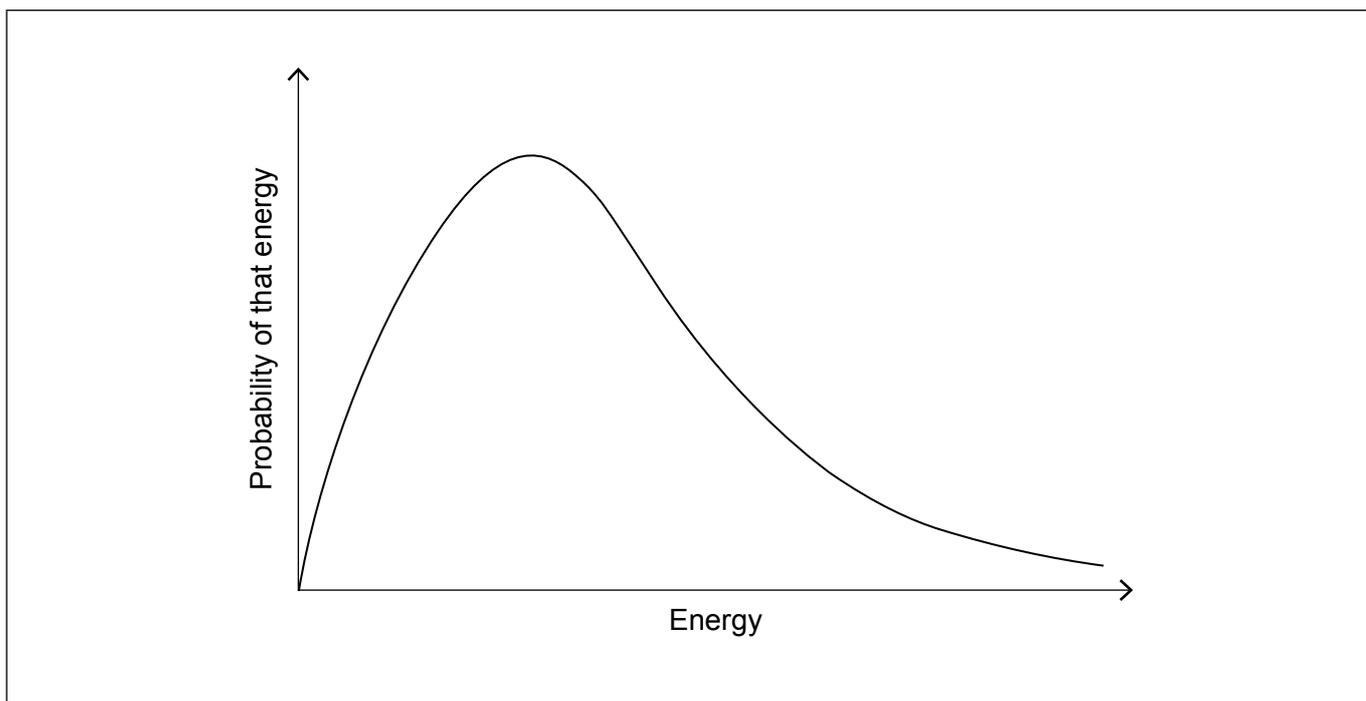
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(iii) Sketch a Maxwell-Boltzmann energy distribution curve at a higher temperature than the one shown. [1]



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(Question 3 continued)

- (iv) Explain why the rate of reaction increases as the temperature is increased. Support your answer by annotating the diagram in (b)(iii). [2]

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- (v) Describe **two** observations which confirm that a solid, added to the reaction mixture, is acting as a catalyst. [2]

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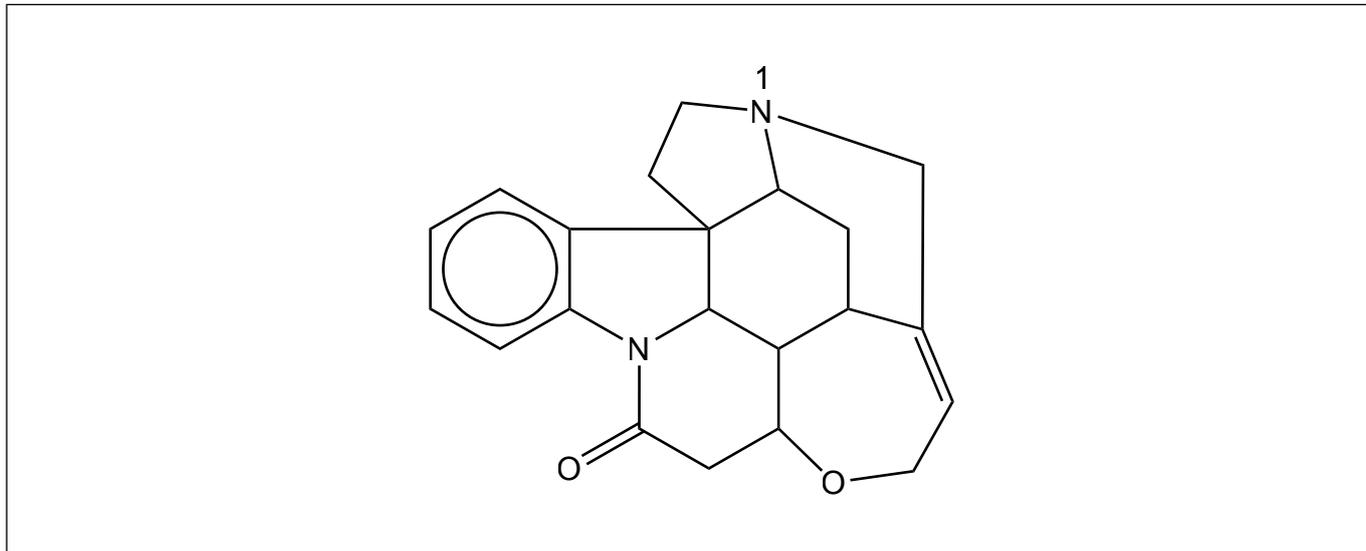
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4. Strychnine, $C_{21}H_{22}N_2O_2$ ($M_r = 334.4$), is a white crystalline solid obtained from plants.

(a) The formula of strychnine is:



(i) State the type of structural formula shown. [1]

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(ii) State the name of the functional group containing the nitrogen atom labelled "1". [1]

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(iii) Outline how the functional group containing N_1 affects the pH when strychnine is dissolved in water. [1]

Direction of pH change:
Reason for change:
.....

(iv) Circle a functional group that would react with bromine in the dark on the diagram in (a). [1]

(This question continues on the following page)



(Question 4 continued)

(v) State the number of rings in strychnine's structure.

[1]

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(b) 48.73 g of strychnine was converted into its sulfate by the reaction:



Determine the percentage yield if 51.41 g of product was obtained. Use section 7 of the data booklet.

[2]

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