



VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE
NAME

CT GROUP

CHEMISTRY

8873/02

Paper 2 Structured Questions

29 August 2025

Candidates answer on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Name and CT group in the spaces at the top of this page.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** the questions.

Section B

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use		
Section A	1	/ 11
	2	/ 20
	3	/ 9
	4	/ 7
	5	/ 13
Section B	6 / 7	/ 20
Total		/ 80

This document consists of **19** printed pages and **1** blank page.

Section A

Answer **all** questions from this section in the spaces provided.

- 1 (a) The element sodium can exist as a number of isotopes.

Complete the Table 1.1 for two isotopes species of sodium.

Table 1.1

Isotopic species	protons	neutrons	electrons	electronic configuration
$^{23}_{11}\text{Na}$	11			$1s^2$
		13	10	$1s^2$

[4]

- (b) Sodium oxide, Na_2O and sodium peroxide, Na_2O_2 are two compounds that can be produced when sodium metal is heated in oxygen under suitable conditions.

Both Na_2O and Na_2O_2 are ionic compounds. Each compound contains only **one** single anion and the charge on each anion is the same.

- (i) Write the formulae of the anions in Na_2O and Na_2O_2 .

..... [1]

- (ii) Draw a 'dot-and-cross' diagram of the anion in Na_2O_2 , showing the outer shell electrons only.

[1]

- (iii) Predict the relative magnitudes of the melting points of Na_2O and Na_2O_2 . Explain your answer.

.....

 [2]

- (c) (i) When the Group 1 cation, $\mathbf{M}^+$, is passed through an electric field, it is deflected through an angle of $+5.0^\circ$.

The angle of deflection is dependent on the relative masses and charge of the particles as shown.

$$\text{Angle of deflection} \propto \frac{\text{charge}}{\text{mass}}$$

Given that the same electric field deflected $^{92}\text{Sr}^{3+}$ through an angle of $+22^\circ$, calculate the relative atomic mass (A_r) of $\mathbf{M}$. Hence suggest a possible identity of the $\mathbf{M}$.

[2]

- (ii) Explain why the second ionisation energy of $\mathbf{M}$ is more endothermic than its first ionisation energy.

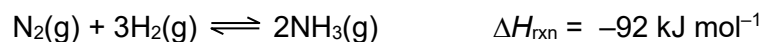
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 [1]

[Total:11]

- 2 Nitrogen is a vital element for sustaining life on Earth. Despite its high abundance in the atmosphere, the availability of reactive nitrogen compounds for biological and industrial use was historically limited. The development of the Haber process for the synthesis of ammonia, followed by the Ostwald process for the large-scale production of nitric acid from ammonia, in the early 20th century marked a significant breakthrough in expanding the availability of reactive nitrogen species for agricultural and industrial applications.

- (a) Ammonia is manufactured from nitrogen and hydrogen by the Haber process as shown in the equation:



Under certain conditions, the system reached dynamic equilibrium with the following gas concentrations.

gas	concentration/ mol dm ⁻³
nitrogen	1.36
hydrogen	1.84
ammonia	0.142

- (i) Explain what is meant by dynamic equilibrium.

.....
 [1]

- (ii) Write an expression for the equilibrium constant, K_c , for the Haber process.

..... [1]

- (iii) Calculate the value of K_c given the following equilibrium concentrations and state the units of K_c .

[2]

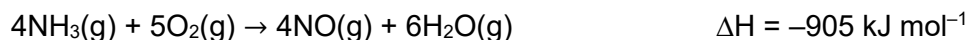
- (iv) Suggest a reason why the activation energy for the Haber process is high.

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

- (v) Describe and explain the conditions required for the favourable production of ammonia in Haber process.

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

- (b) A large proportion of the ammonia manufactured is then used to manufacture nitric acid, which is another industrially important compound. In the chemical industry, synthesis of nitric acid (HNO_3) is commonly carried out via the Ostwald process. The first stage in the process involves the catalytic oxidation of ammonia to nitric oxide (NO):



- (i) Explain, in terms of bonds, why the enthalpy change of the reaction is exothermic.

.....

 [1]

- (ii) Using relevant bond energies in the *Data Booklet* and the given value of enthalpy change for the reaction, determine the N=O bond energy in nitric oxide.

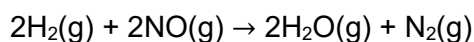
[3]

- (iii) Explain, in terms of frequency of collisions, the effect of increasing the concentration of the reactants on the rate of oxidation of ammonia.

.....

 [2]

(c) A student investigated the reaction between hydrogen gas and nitric oxide.



The following data were obtained.

experiment	initial concentration of $\text{H}_2(\text{g})/\text{mol dm}^{-3}$	initial concentration of $\text{NO}(\text{g})/\text{mol dm}^{-3}$	initial rate/ $\text{mol dm}^{-3} \text{h}^{-1}$
1	1.20×10^{-3}	1.60×10^{-3}	8.00×10^{-4}
2	1.20×10^{-3}	3.20×10^{-3}	3.20×10^{-3}
3	3.60×10^{-3}	1.60×10^{-3}	2.40×10^{-3}

(i) Deduce the orders of reaction with respect to NO and H_2 .

[2]

(ii) Hence, write the rate equation for the reaction.

..... [1]

(iii) Use the data from Experiment 1 to calculate a value for the rate constant.

[1]

(d) An enzyme which was recently discovered was found to catalyse the reduction of nitrite ion, NO_2^- , to nitric oxide, NO.

(i) Write the half-equation for the reduction of nitrite ion, NO_2^- , to nitric oxide, NO.

..... [1]

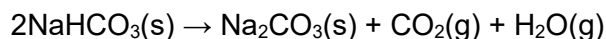
(iv) However, it was also found that the same enzyme is unable to reduce nitrate ions, NO_3^- , to nitric oxide. Suggest an explanation for this.

.....

..... [1]

[Total: 20]

- 3 (a) Baking powder, which is used in cooking, contains sodium hydrogencarbonate, NaHCO_3 . It decomposes on heating according to the equation as shown.



- (i) A sample of baking powder contains 30 % by mass of sodium hydrogencarbonate.

Calculate the volume of carbon dioxide, measured at room temperature and pressure, produced by the total decomposition of the sodium hydrogencarbonate in 7.0 g of the baking powder.

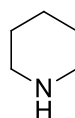
[3]

- (ii) After consuming food or drink containing sugar, the pH in the mouth will decrease as the sugar is broken down into lactic acid. In time, hydrogencarbonate ions in saliva restore the pH into its original value.

Write an ionic equation to show how hydrogencarbonate ions decrease the acidity.

..... [1]

- (b) Piperidine is a monoacidic base and is widely used building block and chemical reagent in the synthesis of organic compounds.



piperidine

- (i) The pH of an aqueous solution of piperidine is 10.1. Calculate the concentration of hydroxide ions in the solution.

[1]

- (ii) In a titration, 25 cm³ of the aqueous solution of piperidine in (b)(i) was found to react completely with 30 cm³ of 0.15 mol dm⁻³ of HCl(aq). Calculate the concentration of piperidine solution.

[1]

- (iii) With reference to your answers to (b)(i) and (b)(ii), explain why piperidine is a weak base.

.....

..... [1]

- (iv) Which of the indicators from the table below could you use for this titration in (b)(ii)?

Indicator	Working range	Low pH colour	High pH colour
Tetrabromophenol blue	3.0 – 4.6	yellow	blue
Thymolphthalein	9.3 – 10.5	colourless	blue

Explain your answer.

.....

.....

.....

..... [2]

[Total:9]

- 4 Titanium dioxide (TiO_2) nanomaterials are being investigated for use in photocatalytic systems. When light is shone onto these materials, reactive species are generated. These reactive species could be applied to water and air purification systems.

One such form of titanium dioxide is nanorods, which have dimensions of 10 nm by 50 nm by 110 nm.

- (a) (i) Explain why titanium dioxide nanorods cannot be classified as nanoparticles.

.....
 [1]

- (ii) Titanium dioxide in its normal, non-nanosized form is known as *bulk* titanium dioxide.

Suggest why titanium dioxide nanorods exhibit much better catalytic properties than bulk titanium dioxide.

.....
 [1]

- (b) Briefly describe one negative impact associated with the use of nanomaterials and nanoparticles in daily life.

.....
 [1]

- (c) Graphene is commonly used in flexible electronic devices such as wearable sensors and foldable displays. These electronic devices can be folded flexibly while still being powered by electrical energy. Their lithium-ion batteries are commonly enhanced by a coating of graphene to improve flexibility and durability.

Explain, in terms of structure and bonding:

- (i) why graphene has high electrical conductivity;

.....

 [2]

- (ii) why graphene is resistant to breaking when pulled or stretched.

.....

 [1]

- (iii) Phosphorene has a structure analogous to graphene. The 3D view of a layer of phosphorene is shown in Fig. 4.1.

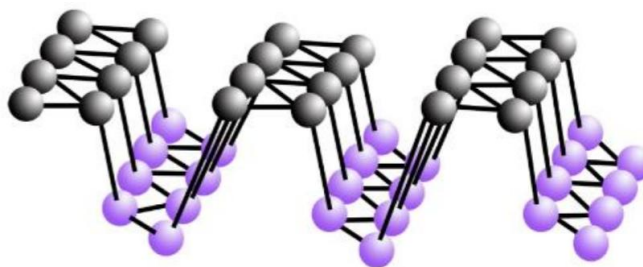


Fig 4.1

With reference to the structures of graphene and phosphorene, suggest why graphene is preferred over phosphorene in the production of ultra-thin electronic devices.

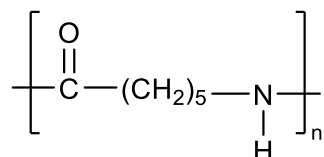
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..... [1]

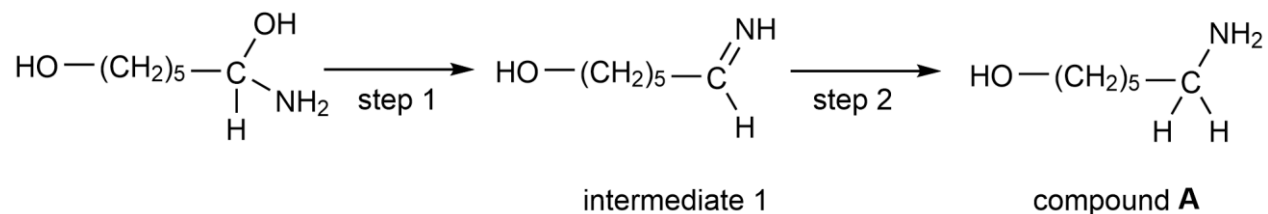
[Total: 7]

- 5 Nylon-6 was one of the earliest synthetic polymers developed for commercial use. Today, it is still used to manufacture items such as womens' stockings.

The structure of nylon-6 is shown below:



Compound **A**, which can be converted to the monomer of nylon-6, is synthesised via the following pathway:



- (a) Name the two functional groups present in compound **A**.

..... [2]

- (b) (i) Suggest the type of reaction taking place in:

step 1:

step 2: [2]

- (ii) Hence, suggest the reagent(s) and conditions for step 2.

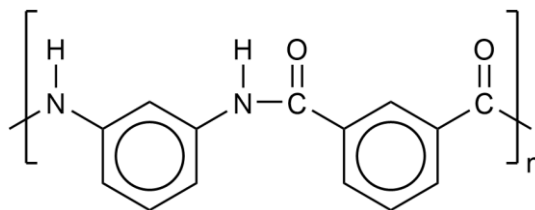
..... [1]

- (c) Describe, in terms of orbital overlap, the formation of the π bond in C=N double bond of intermediate 1. Illustrate your answer with a diagram.

.....
 [2]

- (d) Nomex[®] is another polymer that shares the same type of linkage as nylon-6. However, unlike nylon-6, it is synthesised from two different monomers.

The structure of Nomex[®] is given below.



- (i) Name the type of linkage that is found in both Nomex[®] and nylon-6.

..... [1]

- (ii) Suggest the structures of the two monomers used to synthesise Nomex[®].

[2]

- (iii) Fibres of Nomex[®] and nylon-6 were separately stretched until the fibres tore. The force required to induce tearing of both polymers were measured and recorded.

Suggest the polymer which required a greater force to induce tearing and explain your answer with reference to the structure of the polymer you have chosen.

.....

 [3]

[Total: 13]

6 (a) Aluminium, silicon and phosphorus are elements in the third period of the Periodic Table. Arrange the elements in order of increasing melting point. Explain your answer in terms of structure and bonding.

[4]

- (i) When a few drops of water are added to solid beryllium chloride (BeCl_2), steamy white fumes of hydrogen chloride are evolved and a white solid remains, which is insoluble in water.

..... [1]

- (ii) Hence, write the balanced chemical equation for the reaction between solid beryllium chloride and a small amount of water.

..... [1]

- (iii) Under suitable conditions, ammonia reacts with beryllium chloride via the formation of dative bonds.

Describe how a dative bond is formed between a molecule of ammonia and a molecule of beryllium chloride. Hence suggest the structural formula of the product formed when beryllium chloride reacts with ammonia.

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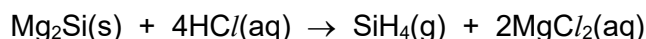
 [2]

- (iv) At 550 °C, beryllium chloride vapour exists as a mixture of BeCl_2 and species **Y**, which has a relative molecular mass of 160. **Y** also contains dative bonds.

Given that the relative molecular mass of the gaseous mixture at 550 °C is 100, determine the percentages of BeCl_2 and **Y** in the gaseous mixture.

[1]

- (c) Silane, SiH_4 , can be produced via the reaction of solid magnesium silicide (Mg_2Si) with dilute hydrochloric acid, as shown in the following equation:



- (i) State and explain whether the silane molecule is polar.

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 [1]

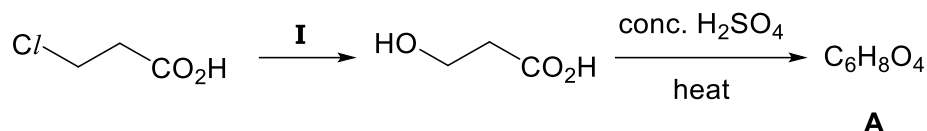
- (ii) Silane gas can be liquefied either by applying high pressure at room temperature or by lowering the temperature at normal pressure.

Explain this phenomenon in terms of intermolecular forces.

.....

 [2]

(d) A series of reactions starting from 3-chloropropanoic acid is shown.



(i) State the type of reaction occurring at reaction I.

..... [1]

(ii) State the reagents and conditions required for reaction I.

..... [1]

(iii) **A** is an 8-membered cyclic compound. Suggest the role of concentrated sulfuric acid, conc. H_2SO_4 , in this reaction and state the type of reaction that has occurred.

.....
 [2]

(e) An organic acid contains 41% carbon, 5% hydrogen and 54% oxygen by mass.

0.090 moles of the acid reacts exactly with 0.18 moles of ethylamine, in the presence of DCC, to produce 0.090 moles of an amide.

(i) Calculate the molecular formula of the acid.

[2]

(ii) Suggest the structure of the organic acid.

[1]

(ii) Suggest the structure of the amide.

[1]

[Total: 20]

- 7 (a) Describe the reactions, if any, of the oxides Na_2O , Al_2O_3 and P_4O_{10} with water. Write an equation for any reaction and state the pH of the resultant mixtures.

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..... [3]

- (b) Sodium is a commercially important alkali metal.

- (i) Explain why sodium metal is typically stored under kerosene oil.

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..... [1]

- (ii) Using relevant data from the *Data Booklet*, compare and explain the reducing power of sodium and potassium.

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..... [3]

- (c) Alloys of aluminium and magnesium are often used in the aircraft manufacture because of their high strength and low density.

A 1.50 g sample of one such alloy was reacted with an excess of aqueous sodium hydroxide. Only aluminium reacted, and 1.50 dm³ of hydrogen gas was produced at room temperature and pressure.

- (i) The aluminium containing product of this reaction is the same as that from the reaction between aluminium oxide and sodium hydroxide. Based on this information, write the equation for the reaction between aluminium and sodium hydroxide.

..... [1]

- (ii) Calculate the percentage by mass of aluminium in the sample of alloy.

If you did not get the equation in (c)(i), then assume 1 mole of aluminium reacts to give 2 moles of hydrogen. This is **not** the correct stoichiometry.

[2]

- (d) (i) Define the term *standard enthalpy change of combustion*, $\Delta H_c^\ominus$, using liquid propanone, CH₃COCH₃, as an example.

Illustrate your answer with a balanced equation, including state symbols.

.....

 [2]

- (ii) When 0.980 g of liquid propanone was combusted using a spirit lamp, the temperature of 100 cm³ of water increased from 25.0 °C to 68.3 °C.

The transfer of the heat evolved in the reaction to the water was only 65 % efficient.

Calculate the enthalpy change of combustion of propanone.

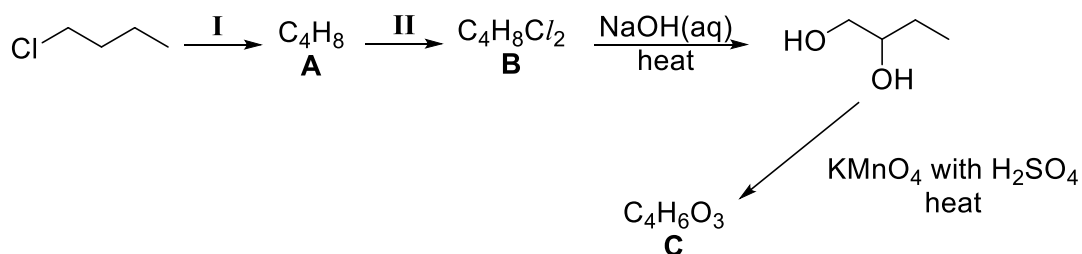
[2]

- (iii) The literature value for the standard enthalpy change of combustion of propanone is $-1790 \text{ kJ mol}^{-1}$.

Suggest why the value calculated in (d)(ii) is less exothermic than the literature value, even though the efficiency of heat transfer to the water was taken into account.

.....
 [1]

- (e) A series of reactions starting from 1-chlorobutane is shown.



- (i) State the reagents and conditions required for reactions I and II.

reaction I:

reaction II: [2]

- (ii) Draw the structural formulae of A, B and C.

A	B	C

[3]

[Total: 20]

