YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	
CG	INDEX NO

CHEMISTRY 9729/02

Paper 2 Structured Questions

10 September 2024

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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

For Examiner's Use		
1		/ 9
2		/ 9
3		/ 16
4		/ 21
5		/ 20
Penalty	units	significant figures
Overall		/ 75

This document consists of **18** printed pages and **6** blank pages.

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Answer **all** the questions in the spaces provided.

1 (a) Calcium carbide, CaC_2 is a solid used in the production of ethyne, C_2H_2.

Calcium carbide is produced when calcium oxide reacts with carbon forming calcium carbide and carbon monoxide.

(i) Write the electronic configuration of calcium in calcium carbide.

..... [1]

(ii) Write an equation, with state symbols for the formation of calcium carbide.

..... [2]

(iii) Predict all possible intermolecular forces which could exist between carbon monoxide molecules. Explain how these forces arise.

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..... [3]

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(b) The German chemist Friedrich Wohler discovered that calcium carbide, CaC_2 reacted with water releasing ethyne gas, C_2H_2 and calcium hydroxide.

The ethyne gas was burnt in miner's lamps and headlights of early motor vehicles for the purpose of illumination.

The equation for the formation of ethyne from calcium carbide is as shown.

$$CaC_2(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq) + C_2H_2(g)$$

An impure sample of calcium carbide of mass 0.752 g was added to 50 cm^3 of water. After all the calcium carbide had reacted, 20.00 cm^3 of the reaction mixture was removed and titrated against 0.250 mol dm^{-3} of hydrochloric acid and 34.60 cm^3 of hydrochloric acid was required to neutralise the sample. It can be assumed that none of the impurities reacted.

Calculate the percentage purity of calcium carbide.

[3]

[Total: 9]

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2 (a) Sodium halides are ionic compounds which have the same crystal structures.

Table 2.1 shows data concerning solubility of sodium halides.

Table 2.1

	value / kJ mol^{-1}
enthalpy change of solution of NaC*l*(s)	−2
enthalpy change of solution of NaI(s)	+2
enthalpy change of hydration of Na^+(g)	−390
lattice energy of NaC*l*(s)	−772
lattice energy of NaI(s)	−694

(i) Use the data in Table 2.1, together with an appropriate energy cycle or otherwise, to calculate a value for the enthalpy change of hydration of the chloride ion.

[2]

(ii) By quoting appropriate data from the *Data booklet*, explain whether the magnitude of enthalpy change of hydration of iodide ion be larger or smaller compared to your answer in **(a)(i)**.

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..... [2]

(b) Lattice energies are not measured directly. By using Hess' Law and Born Haber cycle, they can be obtained from experimental data.

From the knowledge of the distances between cations and anions in the crystal structure, and the charge on each ion, it is possible to calculate the theoretical values for lattice energies.

Table 2.2 shows the numerical values of lattice energies of sodium chloride and sodium iodide.

Table 2.2

compound	experimental value / kJ mol^{-1}	theoretical value / kJ mol^{-1}
NaC*l*(s)	−772	−776
NaI(s)	−699	−685

(i) Define, using sodium chloride as an example, what is meant by the term *lattice energy*.

.....

.....

..... [1]

(ii) There is close agreement between experimental and theoretical values of lattice energy for sodium chloride but not sodium iodide.

Suggest a reason for this.

.....

.....

.....

..... [1]

(c) The ionic radii of some Group 1 metal cations and the halides ions are given in Table 2.3.

Table 2.3

ion	radius, r^+ / nm
Na^+	0.098
K^+	0.133
Rb^+	0.148
Cs^+	0.167

ion	radius, r^- / nm
Cl^-	0.181
Br^-	0.196
I^-	0.219

Complete Table 2.4 and use your results to predict the tastes of sodium bromide and potassium iodide.

Table 2.4

salt	NaBr	KC*l*	NaI	RbC*l*	RbBr	CsC*l*	KI
($r^+ + r^-$)							
taste		salty	salty	salty + bitter	bitter	bitter	

[3]

[Total: 9]

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3 (a) Write equations to show the acidic or basic property of

(i) phenylamine

.....

[1]

(ii) phenol

.....

[1]

(b) Ethylamine, $CH_3CH_2NH_2$, is a weak base.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$

(i) Using the equation given, explain why ethylamine is a *Brønsted-Lowry* base.

.....

[1]

(ii) Identify the two different conjugate acid–base pairs in the equation given.

acid ..... conjugate base .....

base ..... conjugate acid .....

[1]

(iii) The degree of ionisation of $CH_3CH_2NH_2$ in 0.010 mol dm^{-3} aqueous solution is 0.17. Calculate the concentration of OH^- in the solution.

[1]

(iv) Using your answer to **(b)(iii),** calculate a value of the base dissociation constant, K_b, for $CH_3CH_2NH_2$, stating its unit.

[2]

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(c) Fig 3.1 shows a possible reaction sequence with bromomethane as the starting material to form ethylamine.

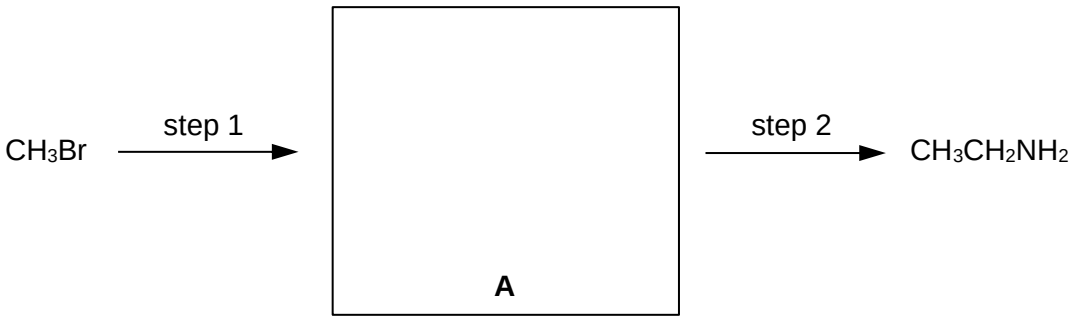

Fig. 3.1

(i) Suggest the reagents and conditions for step 1 and step 2.

step 1 .....

step 2 .....

[2]

(ii) Draw the displayed formula of **A** in the box provided in Fig. 3.1. [1]

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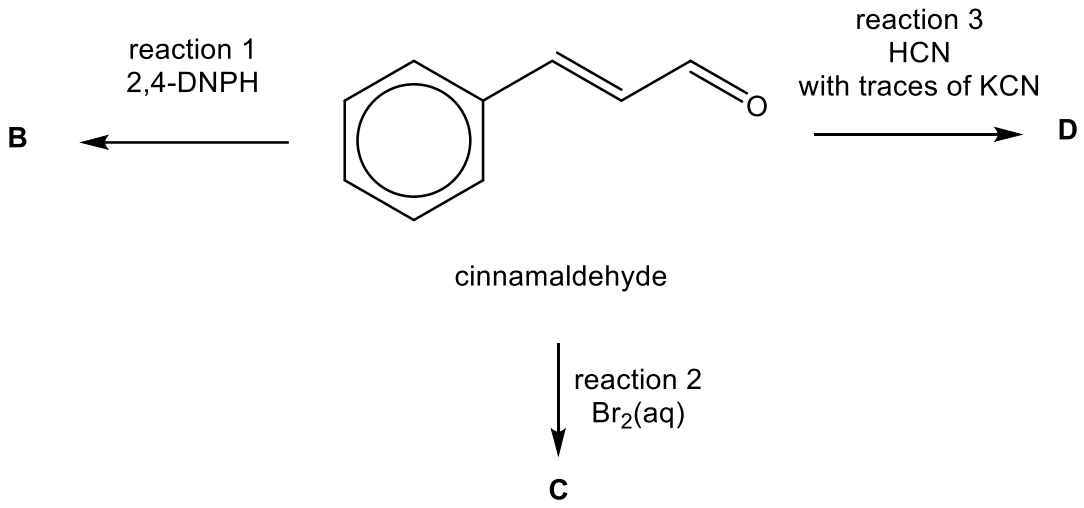
(d) Separate samples of cinnamaldehyde are added to an excess of 3 different reagents.



(i) Suggest the structures of the organic products, **B**, **C** and **D**.

B	
C	
D	

[3]

(ii) State the *types of reaction* that occur during each of the reactions 1, 2 and 3.

reaction 1 .....

reaction 2 .....

reaction 3 .....

[3]

[Total: 16]

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4 Nitrogen dioxide, NO_2 is important in the atmospheric oxidation of sulfur dioxide to sulfur trioxide.

(a) **(i)** Describe and explain, with the aid of suitable equations, the role of NO_2.

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.....

..... [2]

(ii) Describe the reaction of SO_3 with H_2O.
Write an equation to show this reaction and state the pH of the resultant solution.

.....

.....

.....

..... [2]

(b) At room temperature of 25 ^oC, gaseous dinitrogen tetraoxide and nitrogen dioxide are in dynamic equilibrium as shown in the equation.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

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

.....

.....

..... [1]

(ii) Draw a dot-and-cross diagram showing the bonding in NO_2, clearly indicating any co-ordinate (dative covalent) bonds it contains.

[1]

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(iii) Explain, in terms of bond breaking and bond forming, why the decomposition of N_2O_4 is endothermic.

.....

.....

..... [1]

(c) At a temperature of 25 ^oC, 1.00 g of a mixture of N_2O_4 and NO_2 takes up a volume of $3.17 \times 10^{-4}\ m^3$ at a pressure of 101 kPa.

(i) Calculate the average relative molecular mass of the mixture.

[2]

(ii) Deduce qualitatively the effect on the average molecular mass, M_r of the gaseous mixture for each of the following changes.

- increasing pressure,
- increasing temperature.

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..... [3]

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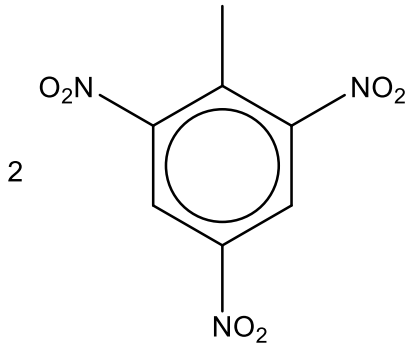
(d) Trinitrotoluene, TNT, is used as an explosive. It can decompose according to the equation shown.



TNT

$$2\ \text{TNT} \longrightarrow 7CO(g) + 7C(s) + 5H_2O(g) + 3N_2(g)$$

(i) Deduce the molecular formula of TNT.

.....

[1]

(ii) When TNT explodes, a black smoke is observed.

Suggest the identity of the black smoke.

.....

[1]

(iii) In practice, TNT is mixed with potassium chlorate(VII), $KClO_4$ for use as an underground explosive to reduce the **hazardous risk**.

Suggest how $KClO_4$ helps to reduce the hazardous risk.

.....

.....

[1]

(iv) The decomposition of Group 1 and Group 2 chlorates(VII) are similar to Group 2 carbonates. Explain why $KClO_4$ decomposes less readily than $Ca(ClO_4)_2$.

.....

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.....

.....

.....

.....

[2]

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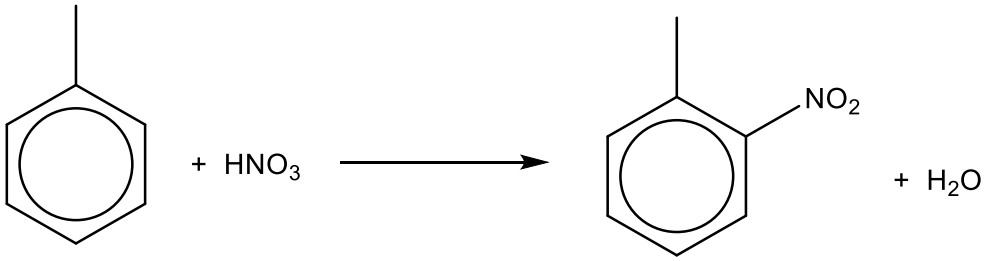
(e) TNT is made by reacting methylbenzene with concentrated HNO_3 in the presence of concentrated H_2SO_4 at 30 °C.

(i) Methylbenzene can react with concentrated HNO_3 in the presence of concentrated H_2SO_4 as shown in the equation.



Name the type of reaction and describe the mechanism for this reaction. Show relevant lone pair of electrons, all charges and using curly arrows to show the movement of electron pairs.

[3]

(ii) The reaction of benzene with concentrated HNO_3 in the presence of H_2SO_4 takes place at 60 °C.
Explain why methylbenzene reacts at lower reaction temperature of 30 °C.

.....

.....

..... [1]

[Total: 21]

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5 Lithium-ion batteries have intercalated lithium compounds as the electrode material. Intercalation is the reversible inclusion or insertion of a molecule (or ion) into materials with layered structures.

When a battery discharges, the cathode is cobalt oxide with intercalated lithium ions, and the anode is graphite with intercalated lithium ions.

In the process of charging and discharging, lithium ions move from one electrode to the other through an electrolyte which is usually lithium salt dissolved in an organic solvent.

If the battery is handled according to the manufacturer's instructions, the elemental lithium is never found in the battery.

(a) When being discharged, the half reaction at the cathode may be assumed to be

$$CoO_2 + Li^+ + e^- \longrightarrow LiCoO_2$$

State the oxidation state of cobalt, Co, in CoO_2 and in $LiCoO_2$.

oxidation state of Co in CoO_2 .....

oxidation state of Co in $LiCoO_2$ .....

[2]

(b) If the battery is overcharged, Li metal can form on one of the electrodes and this can pose a serious fire risk.

State which electrode would Li be formed.

.....

[1]

(c) The commonly used organic solvent for the electrolyte is called EC.

EC has a molecular formula of $C_3H_4O_3$. One of the products of the hydrolysis of EC is 1,2-ethanediol, $HOCH_2CH_2OH$.

(i) Suggest the reagents and conditions in the hydrolysis of EC.

.....

[1]

(ii) Draw the skeletal formula of EC.

[1]

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(d) Lithium burns violently in air producing a mixture of lithium oxide and lithium peroxide, Li_2O_2.

Write the equation for the combustion of lithium assuming the two products are formed in a 1:1 molar ratio.

.....

[1]

(e) On the international space station, compound **F** is used for oxygen storage.
Elemental analysis of compound **F** contains 6.52 % lithium and 33.32 % chlorine by mass.
When decomposed, all the oxygen in compound **F** is converted to molecular oxygen.

Determine the empirical formula of compound **F**.

[2]

(f) The efficiency of a compound to store molecular oxygen is given by its oxygen : volume ratio (OV).

$$\text{OV} = \frac{\text{volume of molecular oxygen released}}{\text{volume of compound that released molecular oxygen}}$$

(i) Using your answer to **5(e)**, write the equation for the decomposition of compound **F**.

.....

[1]

(ii) The density of compound **F** is 2.42 g cm^{-3}.

Calculate the OV of compound **F** at room temperature and pressure.

[3]

Question 5 continues on the next page.

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(g) The Haber process is used to make ammonia, the main use of which is fertilisers that are sprayed on crops. Around 1% of the entire global energy supply is used in the Haber process and hence research groups are looking to find more sustainable methods of producing ammonia.

One recently published approach to making ammonia was the following 3–step method:

step 1: electrolysis of molten lithium hydroxide at 750 K to form lithium metal.

step 2: reaction of Li metal with N_2 to form lithium nitride, Li_3N.

step 3: reaction of lithium nitride with water to reform lithium hydroxide and ammonia.

Lithium hydroxide formed in step 3 can be re-used in step 1 and the process can be repeated.

(i) State the two half-equations that combine to give the overall equation in step 1.

cathode .....

anode .....

[2]

In a small-scale experiment, researchers applied a current of 0.200 A for 1000 seconds.
The yield of Li production in this process was 88.3 %.
The yield of step 2 and step 3 can be assumed to be 100%.

(ii) Calculate the mass of Li generated in step 1.

[3]

(iii) Write balanced equations to show the reaction in step 2 and step 3.

step 2 .....

step 3 .....

[1]

(iv) Calculate the volume of NH_3 produced in cm^3 at s.t.p.

[2]

[Total: 20]

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