EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2022
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CIVICS GROUP	2	1	–			INDEX NUMBER			

CHEMISTRY

9729/02

Paper 2 Structured Questions

15 September 2022
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group, index number on all the work you hand in.
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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 2	
1	/ 20
2	/ 20
3	/ 18
4	/ 17
Total	/ 75

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

For Examiner's Use

1 The carbon family consists of the elements of Group 14. The elements at the top of the group, carbon to germanium, have very different properties from those at the bottom, tin and lead. For instance, Group 14 elements tend to adopt oxidation states of +4, whereas the heavier elements, such as tin and lead, exhibit the +2 oxidation state due to the inert pair effect.

(a) State the valence shell configuration of Group 14 elements.

..... [1]

(b) One of the contributing factors to the inert pair effect is the unexpected increase in the ionisation energies, after lead, down the group.

Explain why the 1st ionisation energies are expected to decrease down the group.

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..... [2]

(c) Carbon forms carbide anion, C_2^{2-} in calcium carbide while silicon mostly forms Si^{4+} ions.

(i) Draw the dot-and-cross diagram of the carbide anion, C_2^{2-}.

[1]

(ii) In a particular experimental set-up, a beam of $^{28}Si^{4+}$ ions was deflected by an angle of +4.2º. Assuming an identical set of conditions, by what angle will the $^{12}C_2^{2-}$ ions be deflected?

[1]

For Examiner's Use

(d) Table 1.1 shows that the melting points of the elements of Group 14.

Table 1.1

element	C	Si	Ge	Sn	Pb
melting point / °C	>3550	1410	937	232	327

Carbon, silicon and germanium each form a solid with the same type of structure. Using bonding and structure, suggest why the melting points of these elements decrease from carbon to germanium.

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..... [2]

(e) Carbon forms many allotropes such as graphite and diamond. Recent scientific research has found that replacing the graphite electrodes with graphene in lithium-ion batteries can extend battery life.

(i) Graphene is a **single, one atom thick** layer of graphite. Describe the hybridisation of the orbitals in, and the bonds between, the carbon atoms within graphene.

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(ii) Using your answer from **(e)(i)**, explain why graphene can conduct electricity along the plane.

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For Examiner's Use

(iii) State and explain how you would expect the bond strength of carbon-carbon bonds in graphene to differ when compared with that in diamond.

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(f) Diamond and graphite are allotropes of carbon. Fig. 1.1 gives the structure of diamond and graphite. Diamond is an important abrasive while graphite is used as a lubricant.

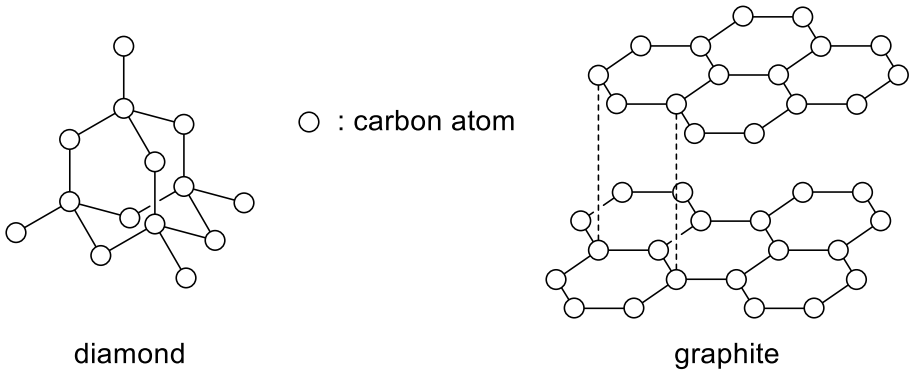

Fig. 1.1

(i) Explain why the sign of the entropy change for the conversion of diamond to graphite is positive.

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..... [2]

For Examiner's Use

(ii) The standard enthalpy change of reaction for the conversion of diamond to graphite is exothermic. Explain whether the conversion of diamond to graphite is spontaneous at all temperatures.

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(iii) In daily life, we do not observe diamond converting to graphite readily. Explain why this is so.

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(g) A three-membered ring cycloalkane, C_5H_{10}, gives only two mono-brominated products with Br_2 under uv light. Only one of the two mono-brominated product is chiral. Give the structural formulae of the cycloalkane and the two mono-brominated products formed. State the ratio in which the two mono-brominated products will be formed.

[3]

[Total: 20]

For Examiner's Use

2 (a) The reaction of secondary halogenoalkanes with NaOH(aq) may be a first order or second order reaction.

0.0500 mol dm^{-3} $(C_6H_5)CHBrCH_3$ was reacted with 2.00 mol dm^{-3} NaOH(aq) at a constant temperature and the half-life is constant at 277 seconds.

(i) Explain the meaning of the following terms:
- order of reaction
- half-life

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..... [2]

(ii) Although the half-life of the experimental study is constant, explain why the half-life of the reaction cannot be used to determine whether the reaction takes place via an S_N1 or S_N2 mechanism.

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..... [1]

For Examiner's Use

(iii) Optically pure $(C_6H_5)CHBrCH_3$ reacts with NaOH via an S_N1 mechanism. Describe the mechanism. In your answer, show any relevant charges, dipoles or lone pairs of electrons you consider important in the mechanism.

[2]

(iv) Suggest, with reference to the mechanism in **(a)(iii)**, why the product does not rotate plane polarised light.

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..... [2]

(v) With reference to the mechanism in **(a)(iii)**, write the rate equation for the reaction between $(C_6H_5)CHBrCH_3$ and NaOH(aq). Hence, calculate the rate constant.

[2]

For Examiner's Use

(vi) Suggest and explain how the rate of reaction would change if

- the temperature of the reaction was increased

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..... [2]

- $(C_6H_5)CHBrCH_3$ was changed to $(C_6H_5)CHCl CH_3$ of the same concentration.

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(vii) Water is a more polar solvent than ethanol. With reference to the mechanism in **(a)(iii)**, explain why the rate of S_N1 substitution is lowered when NaOH(aq) is replaced by ethanolic NaOH.

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..... [1]

For Examiner's Use

(b) The Haber process uses atmospheric nitrogen and hydrogen to produce ammonia gas. When a mixture comprising 1.0 mol of nitrogen and 3.0 mol of hydrogen initially was left to equilibrate in a closed vessel maintained at 500 ºC and 250 atm, 0.70 mol of ammonia was attained when the system reached equilibrium.

(i) Calculate the K_p for the following equilibrium.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

[3]

(ii) Hence or otherwise, calculate the K_p for the following equilibrium.

$$4NH_3 \rightleftharpoons 2N_2 + 6H_2$$

[1]

(iii) Helium gas was injected into the equilibrium mixture under constant volume. Explain how the amount of ammonia would change.

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..... [2]

[Total: 20]

For Examiner's Use

3 For redox reactions in acidic medium under standard conditions, their $E^{\ominus}$ values from the *Data Booklet* are valid only at pH 0. However, the pH in typical biological systems is usually around 7. Hence, a new type of reduction potential specific to pH 7 has been defined, which is known as formal reduction potential, $E^{\ominus}_{\text{formal}}$.

The $E^{\ominus}$ and $E^{\ominus}_{\text{formal}}$ values for some important reactions are given in Table 3.1. Reactions which $E^{\ominus}$ values have not been experimentally determined are not indicated.

Table 3.1

	half-equation	$E^{\ominus}$/V	$E^{\ominus}_{\text{formal}}$/V
1	$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23	+0.82
2	oxaloacetate + $2H^+ + 2e^- \rightleftharpoons$ malate	+0.33	–0.17
3	$NAD^+ + 2H^+ + 2e^- \rightleftharpoons NADH + H^+$	–0.11	–0.32
4	$FAD + 2H^+ + 2e^- \rightleftharpoons FADH_2$	–	–0.22

(a) Based on the data in Table 3.1, explain why the $E^{\ominus}_{\text{formal}}$ is less positive than $E^{\ominus}$ for the reduction of O_2 gas.

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..... [1]

Fig. 3.1 shows the schematic diagram of the citric acid cycle that involves some application of reactions given in Table 3.1. All reactants and products involved in the citric acid cycle are in the aqueous state.

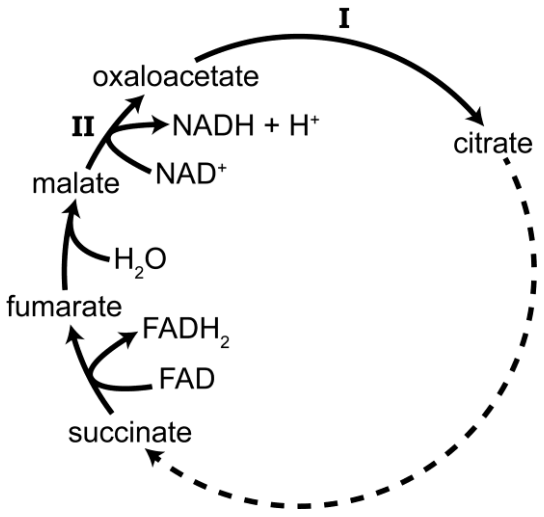

Fig. 3.1

For Examiner's Use

(b) FAD and NAD^+ are two oxidising agents used in the citric acid cycle. With reference to the $E^{\ominus}_{formal}$ values in Table 3.1, explain whether FAD or NAD^+ is a better oxidising agent.

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..... [1]

(c) Calculate $\Delta G^{\ominus}_{formal}$ for step **II**.

[2]

(d) In the citric acid cycle, it is noted that the consumption of oxaloacetate in step **I** occurs at a much faster rate than the production of oxaloacetate in step **II**.

(i) State the effect on the concentration of oxaloacetate due to the difference in reaction rates of the 2 steps.

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..... [1]

(ii) Based on your answers in **(c)** and **(d)(i)**, suggest how this can cause step **II** to become more spontaneous.

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..... [1]

For Examiner's Use

(e) A student was tasked to electroplate the surface of a steel tank with copper metal using the set-up in Fig. 3.2. A galvanic cell to generate the electricity is required for the electroplating process.

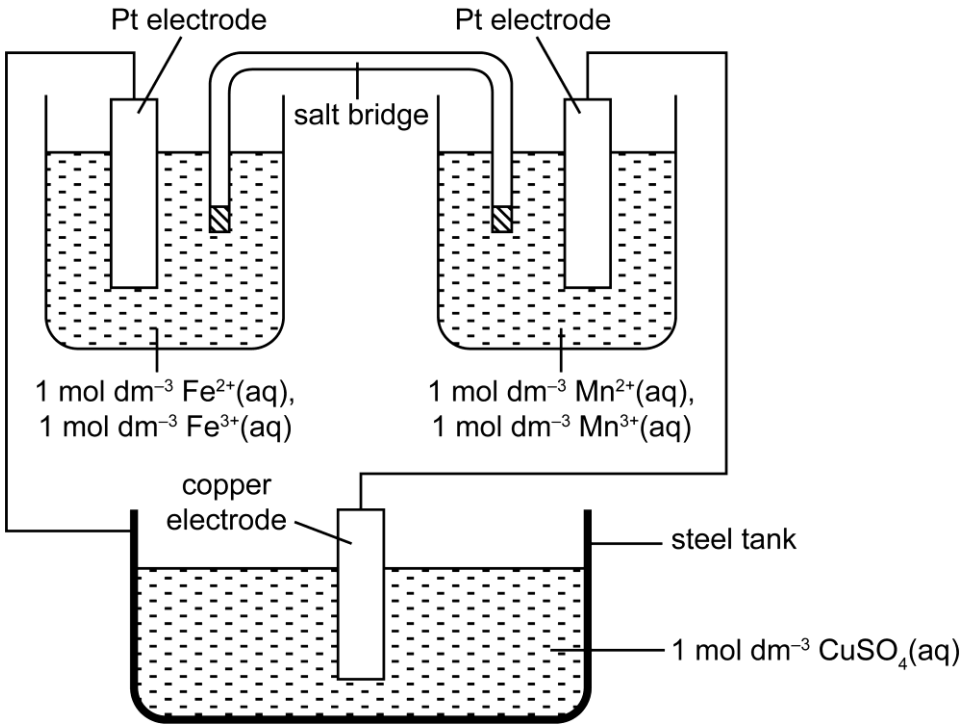

Fig. 3.2

(i) With reference to the *Data Booklet*, construct an equation for the overall reaction in the galvanic cell.

..... [1]

(ii) Indicate the polarity of the electrodes in both the galvanic and electrolytic cells and the direction of electron flow between the galvanic and electrolytic cells in Fig. 3.2 [3]

(iii) Explain why the electrolytes used in the galvanic cell need to be separated into two half-cells in Fig. 3.2.

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..... [1]

For Examiner's Use

(f) Celestine is a blue mineral that contains $SrSO_4$. When $SrSO_4$ is heated strongly, it decomposes to form a metal oxide and releases two different colourless gases. One gas rekindles a glowing splint, while the other is SO_2.

(i) Construct the balanced equation, including state symbols, for the thermal decomposition of $SrSO_4$.

..... [1]

(ii) Explain why $SrSO_4$ decomposes at a higher temperature than $MgSO_4$.

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..... [2]

(iii) 5.00 g of $SrSO_4$ and $MgSO_4$ were separately heated strongly using the same heat source for an extended period of time. Fig. 3.3 shows how the volume of gas varies with time of heating for $MgSO_4$. Sketch on Fig. 3.3 the graph of total volume of gas evolved against time of heating for $SrSO_4$.

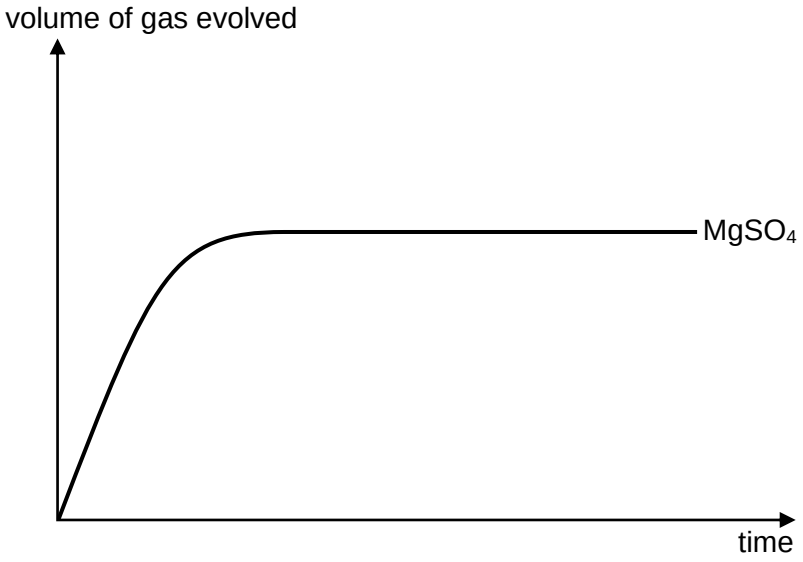

Fig. 3.3

[2]

For Examiner's Use

(iv) When 2.15×10^{-8} mol of $SrSO_4$ powder is added to 25.0 cm^3 of 0.400 mol dm^{-3} K_2SO_4(aq) at 298 K, the solution of $SrSO_4$ just reaches saturation with all the $SrSO_4$ dissolved. Calculate the K_{sp} of $SrSO_4$ and state its units.

[2]

[Total: 18]

For Examiner's Use

4 Phenylamine, $C_6H_5NH_2$, is the simplest aromatic amine. Its main use is in the manufacture of phenyl isocyanate, C_6H_5NCO, a precursor to polyurethane, dyes, and other industrial chemicals.

(a) The carbon atom of the isocyanate group has a similar shape as that in CO_2. Draw the displayed formula of phenyl isocyanate, C_6H_5NCO.

[1]

(b) The shape of the nitrogen atom of phenyl isocyanate is bent. Hence, state the hybridisation state of the nitrogen atom of phenyl isocyanate. Suggest a bond angle for this nitrogen atom.

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..... [2]

(c) At 380 ºC, 1.00 g of gaseous phenylamine has a measured pressure of 950 kPa and volume of 5.90×10^{-5} m^3.

(i) Assume ideal behaviour, show the molar mass of phenylamine is 96.8 g mol^{-1}.

[1]

(ii) The actual relative molecular mass of phenylamine is 93.0. As all the data are measured accurately, explain why the experimental calculated molar mass in **(c)(i)** is higher than the actual value.

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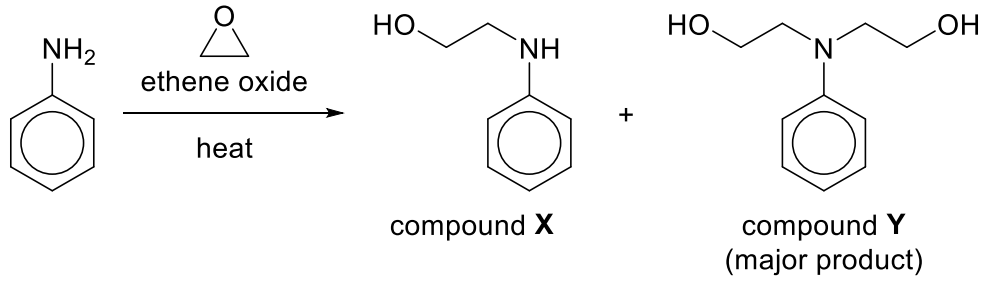
..... [1]

For Examiner's Use

(d) When an equimolar mixture of phenylamine and ethene oxide is heated, a mixture of products was formed via the nucleophilic substitution mechanism.

Compound **X** that is first formed reacts further with unreacted ethene oxide, giving compound **Y** as the major product.



compound **X**

compound **Y**
(major product)

(i) Explain why ethene oxide reacts preferentially with compound **X**, rather than with phenylamine itself.

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..... [2]

(ii) Besides compound **Y**, the reaction between compound **X** and unreacted ethene oxide also gave a byproduct, compound **Z**, via nucleophilic substitution.

Compounds **Y** and **Z** are constitutional isomers. Suggest the structure of compound **Z** and explain why compound **Z** is not formed in significant quantities as compared to compound **Y**.

Explanation: .....

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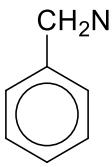
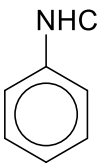
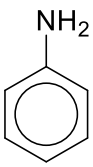
..... [2]

For Examiner's Use

(e) The reactivity of three nitrogen-containing compounds with aqueous bromine is shown in Table 4.1

Table 4.1

	 benzylamine	 acetanilide	 phenylamine
reactivity with Br_2(aq) at room temperature	no reaction	mono-substitution of benzene ring	tri-substitution of benzene ring

(i) Explain the difference in the reactivity of the three compounds with Br_2(aq).

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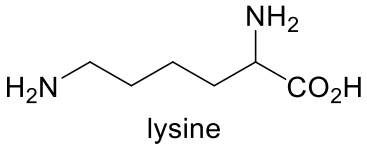
..... [3]

(ii) Write a balanced equation for the reaction between phenylamine and Br_2(aq) at room temperature.

[1]

For Examiner's Use

(f) Lysine is an α-amino acid that is used in the biosynthesis of proteins.



lysine

It is an essential amino acid because human body cannot make it, so it must be obtained from food.

The pK_b values of lysine are 11.8, 5.1 and 3.5, with the α-amino group being the weaker base between the two amino groups.

(i) The fully deprotonated form of lysine is shown in Fig. 4.1. Fill in the pK_b values in the respective boxes.

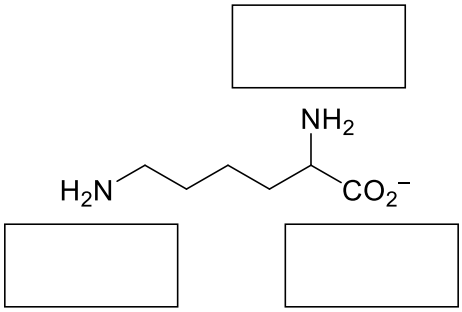


Fig. 4.1 [1]

(ii) Suggest a reason why the α-amino group of lysine is less basic than the amino group on the side chain.

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..... [1]

(iii) Draw the zwitterionic form of lysine and state the pH range at which the zwitterion will exist as the major species.

pH range: ..... [1]

(iv) The zwitterion of lysine can act as a buffer agent in the blood. Write an equation showing how the zwitterion regulate the pH when a small amount of acid is added.

For Examiner's Use

[1]

[Total: 17]

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