

VICTORIA JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION Higher 2

CANDIDATE NAME

CT GROUP

CHEMISTRY

Paper 2 Structured Questions

Candidates answer on the Question Paper.

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 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 / 20			
2	/ 22		
3	/ 16		
4	/ 17		
Total	/ 75		

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2 hours

12 September 2024

This document consists of 20 printed pages.

1 (a) The Pauling electronegativity values, E_N , for the elements in the first two periods of the Periodic Table range from 1.0 to 4.0. The elements **X**, **Y** and **Z** are all in the first two periods of the Periodic Table. Their E_N values are shown in Table 1.1.

element	E _N
Х	1.0
Y	2.1
Z	4.0

Table 1.1

Substances exist with formulae XZ, YZ and Z₂.

(i) Use Table 1.1 to deduce the group of the Periodic Table that **X** and **Z** belong to.

		X belongs to Group
		Z belongs to Group[1]
	(ii)	Suggest the structure and bonding present in XZ.
		[1]
	(iii)	Arrange XZ, YZ and Z ₂ in order of increasing melting point.
(b)	(i)	Write the full electronic configuration of an aluminium atom.
	(ii)	Write an equation to show the third ionisation energy of aluminium.
		[1]
	(iii)	Explain why the third ionisation energy of aluminium is greater than the first ionisation energy of sodium.
		[2]

(c) Two Period 3 elements, U and V, burn separately in oxygen to form solid oxides. The oxide of U is insoluble in water. The oxide of V dissolves in water to form solution W. Solution W reacts with the oxide of U at room temperature and dissolves it. V has a larger atomic radius than U.

3

- (i) Identify U and V. **U** is **V** is [2] (ii) Write an equation for the reaction between oxide of U and solution W.[1] (d) (i) State the total numbers of protons, neutrons and electrons in the NO_3^- ion. Total number of protons: Total number of neutrons: Total number of electrons: [1] (ii) Similar to carbonate salts, copper(II) nitrate, Cu(NO₃)₂, and barium nitrate, Ba(NO₃)₂,
 - decompose when heated. Compare the decomposition temperatures of these two compounds. Explain your answer.

(iii) Sketch the shape of and label a filled orbital in Cu²⁺(aq) ion with the highest energy in Fig. 1.1.





(iv) Compound T, an anhydrous Group 2 bromide, is dissolved in water and titrated against aqueous silver nitrate.

A solution containing 0.250 g of **T** requires 33.65 cm³ of 0.0500 mol dm⁻³ AgNO₃(aq) for complete reaction. Identify **T**. Show your working.

[2]

(e) HCl is a product of several different reactions. Some of these are shown in Fig. 1.2.

SiCl₄ $\xrightarrow{H_2O}$ HCl $\xrightarrow{Concentrated}$ H2SO₄ NaCl



(i) Describe the reaction of $SiCl_4$ with water in reaction 1. Write an equation for the reaction and state the pH of the resultant mixture.

......[1]

In reaction 2, NaCl reacts with concentrated H_2SO_4 to form HCl and NaHSO₄ only. Similarly, NaBr reacts with concentrated H_2SO_4 to form HBr and NaHSO₄. HBr reacts further with concentrated H_2SO_4 to form Br₂ and SO₂.

(ii) State the types of reaction that occur when NaBr reacts with concentrated H₂SO₄ and when HBr reacts with concentrated H₂SO₄.

reactants	type of reaction
NaBr and concentrated H_2SO_4	
HBr and concentrated H ₂ SO ₄	

[1]

(iii) Write an equation for the reaction of HBr with concentrated H₂SO₄.

......[1]

(iv) Suggest an explanation for the difference in the reactions when HCl and HBr react with concentrated H_2SO_4 .

[1]

[Total: 20]

2 (a) The reaction between iron(III) ions, $Fe^{3+}(aq)$, and iodide ions, $I^{-}(aq)$, occurs as shown.

 $\mathsf{Fe}^{\scriptscriptstyle 3\text{+}}(\mathsf{aq}) + \mathrm{I}^{\scriptscriptstyle -}(\mathsf{aq}) \to \mathsf{Fe}^{\scriptscriptstyle 2\text{+}}(\mathsf{aq}) + \tfrac{1}{2} \mathrm{I}_2(\mathsf{aq})$

The rate of this reaction can be followed by the change in the $I^-(aq)$ concentration as given in the graph in Fig. 2.1. The initial concentration of $Fe^{3+}(aq)$ is 0.150 mol dm⁻³.



Fig. 2.1

(i) Use Fig. 2.1 to calculate the initial rate of reaction and the rate of reaction at 20 s. Show your working on the graph.

(ii) Hence, determine the order of reaction with respect to the concentration of iodide ions. Show your working.

(iii) Explain why it is important that the concentration of Fe³⁺(aq) is in large excess compared to the concentration of I⁻(aq) in this experiment.

[1]

(iv) It is found that the reaction is first order with respect to the concentration of $Fe^{3+}(aq)$. Write the rate equation for the reaction between $Fe^{3+}(aq)$ and $I^{-}(aq)$.

.....[1]

(v) Use the rate equation and the initial rate you have determined in (a)(i) to calculate the rate constant, stating the units.

[2]

(vi) A new experiment of the same reaction was carried out at a different temperature. The value of the rate constant was found to be 2.10. Deduce whether the new experiment was carried out at a higher or lower temperature than the original experiment.

......[1]

[Turn over

(b) The halogens, chlorine and bromine, are moderately soluble in water, while iodine is sparingly soluble. The dissolution of chlorine in water occurs with the two equilibria as shown.

 $Cl_2(\mathbf{q}) \rightleftharpoons Cl_2(\mathbf{aq}) \quad \stackrel{\text{----}}{\longrightarrow} (\mathbf{I})$ $Cl_2(\mathbf{aq}) + 2H_2O(\mathbf{I}) \rightleftharpoons H_3O^+(\mathbf{aq}) + Cl^-(\mathbf{aq}) + HOCl(\mathbf{aq}) \quad \stackrel{\text{-----}}{\longrightarrow} (\mathbf{II})$

(i) Describe the effect of the presence of aqueous hydroxide ions on the solubility of chlorine in water.

(ii) Complete Table 2.1 to describe the covalent bonds formed and the types of interactions that are overcome and formed for the various **chlorine species** in equilibrium (II) when chlorine is dissolved in water. An example is shown below.

covalent bond broken	$Cl-Cl$ bond in Cl_2
covalent bond formed	
type of interactions overcome	
	(1)
types of interactions formed	(2)
	[2]

Table 2.1

(c) The oxyacids of chlorine are shown in Table 2.2.

Table 2.2

HOCI HOCIO		HOC1O2	HOC1O3
chloric(I) acid	chloric(III) acid	chloric(V) acid	chloric(VII) acid

(i) State how the values of the acid dissociation constant, K_a , change from chloric(I) acid to chloric(VII) acid. Explain your answer in terms of the delocalisation of electrons.

(ii) 1.00 g of a sodium salt of an oxyacid of chlorine is dissolved in 100 cm³ of water. 10.0 cm³ of the solution requires 11.25 cm³ of 0.25 mol dm⁻³ acidified H₂O₂ for complete reaction. The only chlorine-containing product formed in the reaction is Cl^{-} . Deduce the formula of the sodium salt. Show your working.

[3]

(iii) The chlorate(VII) ion, C*l*O₄⁻, can be produced from the reaction of C*l*₂O₇ with alkali. Given that the C*l*₂O₇ molecule is non-cyclic and symmetrical, draw the structure of the molecule, indicating the bond angles around C*l* and O atoms. (d) Two solutions are prepared as described below.

Solution **P** is made by mixing 50.0 cm³ of 2.00 × 10^{-3} mol dm⁻³ HC*l*(aq) with 50.0 cm³ of 2.00 mol dm⁻³ NaC*l*(aq) and has a pH of 3.00. If 1.0 cm³ of 1.00 mol dm⁻³ HNO₃(aq) is added to **P**, the pH changes to 1.96.

10

Solution **Q** is made by mixing 50.0 cm³ of 0.100 mol dm⁻³ HF(aq) with 50.0 cm³ of 0.100 mol dm⁻³ NaF(aq) and has a pH of 3.20. If 1.0 cm³ of 1.00 mol dm⁻³ HNO₃(aq) is added to **Q**, the pH changes to 3.02.

(i) Use the data given about solution **P** to prove that HCl(aq) is a strong acid.

(ii) Use the data given about solution **Q** to calculate the pH of 0.100 mol dm⁻³ of HF(aq).

[Total: 22]

- 3 (a) (i) State two basic assumptions of the kinetic theory as applied to an ideal gas.
 [1]
 (ii) Explain why a real gas will deviate more from ideality at a lower temperature.
 - (iii) Calculate the concentration, in mol dm⁻³, of a gaseous bromine sample with a partial pressure of 23.3 kPa at 298 K.

[1]

(b) Pyridinium tribromide can be used in the synthesis of mono-brominated anilide. There are two possible routes to this synthesis starting from phenylamine as shown in Fig. 3.1.



Fig. 3.1

You may assume pyridinium tribromide in ethanol has the same reactivity as aqueous bromine. The line connecting Br to the benzene ring in Fig. 3.1 indicates that Br is attached to one of the carbon atoms in the benzene ring.

Ethanoic anhydride, 70, is used as a safer alternative to ethanoyl chloride in reactions.

(i) Suggest the type of reaction for step 1 and step 2 of Route 1.

(ii) **Route 1** is the preferred route for the synthesis because it produced mostly mono-brominated anilide while **Route 2** produced mostly multi-brominated anilide. Suggest an explanation for this observation.

.....

-[1]
- (iii) The major product obtained in step 2 of **Route 1** is 4-bromoanilide instead of 2-bromoanilide. Suggest an explanation for this yield.

.....[1]

(c) Acyl chlorides react with sodium carboxylates to form acid anhydrides as shown in Fig. 3.2.



Fig. 3.2

The condensation polymers, polyanhydride and polyester, are formed by similar methods. One repeat unit for a polyanhydride is shown in Fig. 3.3.



Fig. 3.3

Use Fig. 3.2 and Fig. 3.3 to suggest the structures of the two monomers used to make this polyanhydride.



(d) Equilibrium systems involving tribromide have been studied extensively, one of which is shown below.

reaction 1 $Br_2(aq) + Br^-(aq) \Rightarrow Br_3^-(aq)$ $K_c = 100 \text{ at } 298 \text{ K}$

Reaction 1 is considered as *virtually complete* if more than 95% of the limiting reagent is reacted. When 32.0 mg of bromine was dissolved in 250 cm³ of 0.500 mol dm⁻³ sodium bromide solution, the reaction *might be* virtually complete.

(i) Calculate the initial concentration of Br₂ in the mixture.

(ii) Give two reasons why reaction 1 might be virtually complete.

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(iii) Write the expression for equilibrium constant K_c for reaction 1.
[1]
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[1]

(iv) Determine the concentration of Br₂ in the mixture at equilibrium. Show your working. Hence, conclude if reaction 1 is *indeed* virtually complete.

[3]

[Total: 16]

4 (a) 4-hydroxybutanal forms a cyclic hemiacetal in the presence of an acid catalyst as shown in Fig. 4.1.



Fig. 4.1

- (i) The mechanism involves three steps.
 - Step 1: The aldehyde is protonated by the acid catalyst to form a non-cyclic intermediate.
 - Step 2: Nucleophilic attack by the alcohol to form a cyclic intermediate.
 - Step 3: Deprotonation of the cyclic intermediate to form the product.

Suggest the three-step mechanism for this reaction. Show all charges, relevant lone pairs, curly arrows and the structures of intermediates formed.

(ii) Describe a simple chemical test to distinguish 4-hydroxybutanal from cyclic hemiacetal as shown in Fig 4.1. Include the reagents and conditions and the expected observations with each compound. Write an equation for the reaction that occurs.

(iii) The cyclic hemiacetal shown below exists as a mixture of stereoisomers. State the number of stereoisomers and suggest how their physical properties differ.



cyclic hemiacetal

[2]	 	 	

(b) Compound W has the molecular formula C₇H₇OC*l*. It is an aromatic compound which contains two functional groups. Data about the reactions of W are given in Table 4.1.

Table 4	4.1
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reaction	reagent	result
1	AgNO₃(aq), warm	white solid formed which is soluble in an excess of $NH_3(aq)$
2	excess Br ₂ (aq)	white solid formed which has $M_{\rm r} = 379.2$
3	acidified MnO₄⁻, heat under reflux	MnO_4^- is decolourised; one organic product formed with $M_r = 138$
4	Na	colourless gas evolved; white solid formed which is soluble in H_2O
5	NaOH(aq) at room temperature	colourless solution formed

(i) Name the functional group that reaction 1 shows to be present in W.

	[1]
(ii)	Based only on reaction 4, give the names of two different functional groups that could be present in ${\bf W}$.
	[1]
(iii)	Which of the functional groups you have named in (b)(ii) is confirmed by reaction 5? Explain your answer.
	[1]
(iv)	Deduce the molecular formula of the organic product formed in reaction 3.
	[1]
(v)	Identify the two reactions that confirm W is aromatic.
	[1]

(vi) Draw the displayed formula of W.

(vii) Explain clearly why you have placed **one** of the two functional groups in that particular position.

[1]

(c) A polypeptide **H** was analysed and found to contain the following amino acids as shown in Table 4.2.

amino acid	aspartic acid	glycine	serine	tyrosine	valine
abbreviation	asp	gly	ser	tyr	val
R group	–CH ₂ CO ₂ H	_H	–CH₂OH	CH ₂ OH	–CH(CH ₃) ₂
number of residues	1	1	2	1	1

Table 4.2

Analysis of polypeptide H gave the following results.

- The N-terminus was shown to be ser.
- On reaction with the enzyme chymotrypsin, which hydrolyses at the carboxylic acid end of tyr, **H** gave two tripeptides.
- On reaction with a reagent which digests at the carboxylic end of val, **H** gave two peptides. One of these two was a dipeptide of sequence gly–ser.
- (i) Draw the structure of the dipeptide gly-ser.

(ii) Explain why a sample of serine has a high melting point.

(iii) Determine the amino acid sequence of polypeptide **H**. You should use the same 3–letter abbreviations as shown in Table 4.2 to write out the amino acid sequence.

[1]
Г	· ' ·	1

[Total: 17]