Anglo-Chinese Junior College

JC2 Preliminary Examination
Higher 1

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		FORM CLASS	
TUTORIAL CLASS	2CHX _ _	INDEX NUMBER	

CHEMISTRY

8873/02

Paper 2 Structured Questions

27 Aug 2025
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and index number in the spaces on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section **A**
Answer **all** questions.

Section **B**
Answer **one** question.

The use of 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 Examiners' use only	
Section A	
1	/ 13
2	/ 7
3	/ 10
4	/ 7
5	/ 13
6	/ 10
Section B	
7 or 8	/ 20
Total	/ 80

Section A

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

1 In the presence of an acid catalyst, ethanal reacts with methanol to form 1,1-dimethoxyethane.

$$CH_3CHO(l) + 2CH_3OH(l) \overset{H^+}{\rightleftharpoons} CH_3CH(OCH_3)_2(l) + H_2O(l)$$

ethanal methanol 1,1-dimethoxyethane

(a) 0.20 mol dm^{-3} of ethanal and 0.1 mol dm^{-3} of methanol were placed in a reaction vessel. Strong acid was then added as a catalyst. It was found that the equilibrium mixture contained 0.025 mol dm^{-3} of 1,1-dimethoxyethane.

Calculate the equilibrium concentrations of the other reactants and products.

[3]

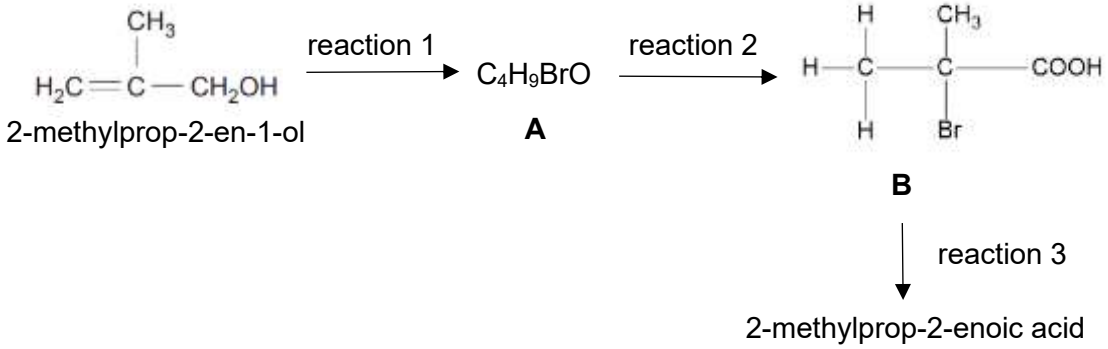
(b) Write the expression for the equilibrium constant for this reaction, K_c, stating its units.

[2]

(c) Use your answers in **(a)** to calculate the value of K_c.

[1]

(d) 2-methylprop-2-enoic acid can be obtained from 2-methylprop-2-en-1-ol.



(i) To prevent the C=C bond from reacting in other reactions, reaction 1 is first carried out.

Draw the structure of **A**.

[1]

(ii) Suggest the reagent used in reaction 1.

……..….[1]

(iii) Name the type of reaction in reactions 2 and 3.

reaction 2: ……

reaction 3: …… [2]

(iv) Draw the displayed formula of 2-methylprop-2-enoic acid.

[1]

(v) Suggest a chemical test to distinguish between 2-methylprop-2-en-1-ol and **B**.

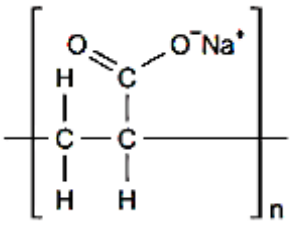
State the observations.

…….

……..….[2]

[Total: 13]

2 (a) Sodium polyacrylate is a superabsorbent polymer that can absorb and retain large amounts of water relative to its own mass. It is widely used in diapers.



(i) Draw the monomer used to make sodium polyacrylate.

[1]

(ii) Explain why this polymer is an addition polymer.

……

……[2]

(iii) Using the information provided above, explain, in terms of structure and bonding, the property of this hydrogel.

……

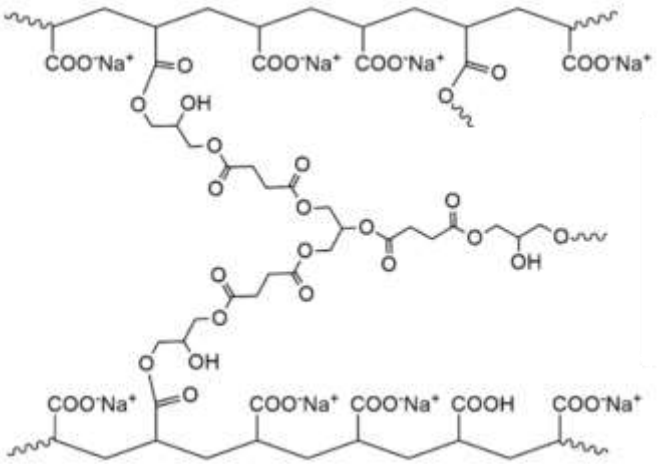
……[1]

(iv) In an experiment, 4.0×10^{-6} mol of polymer absorbed 150 g of water. This mass of water is 300 times the mass of polymer used.

Calculate the relative molecular mass of the polymer.

[1]

(v) After polymerisation, sodium polyacrylate is further processed to form crosslinked sodium polyacrylate found in commercial products. The following diagram shows the structure of crosslinked sodium polyacrylate.



Explain how crosslinking of sodium polyacrylate allows it to remain as a solid mass in wet diapers.

……

……

……[2]

[Total: 7]

3 **(a)** The noble gas xenon was once thought to be inert. It has since been discovered that xenon will react with strong oxidants. For example, xenon reacts with fluorine gas, forming a series of fluorides, XeF_2, XeF_4 and XeF_6.

(i) Draw dot-and-cross diagram of xenon difluoride and state its bond angle.

[2]

(ii) Name the shape of xenon difluoride.

.....[1]

(iii) Explain the three-dimensional arrangement using the principles of the VSEPR theory.

……..……..

……..……..

……..….[2]

(b) The boiling points of some fluoride compounds are shown in Table 3.1.

Table 3.1

compound	M_r	boiling point/ ^oC
CF_4	88	−127.8
CIF_3	92.5	11.8
PF_3	88	−101.8

Explain the difference in boiling points using structure and bonding.

……..……..……..

……..……..……..

……..….[3]

(c) Explain why the ionic bond in lithium iodide, LiI, has greater covalent character than that of lithium fluoride, LiF.

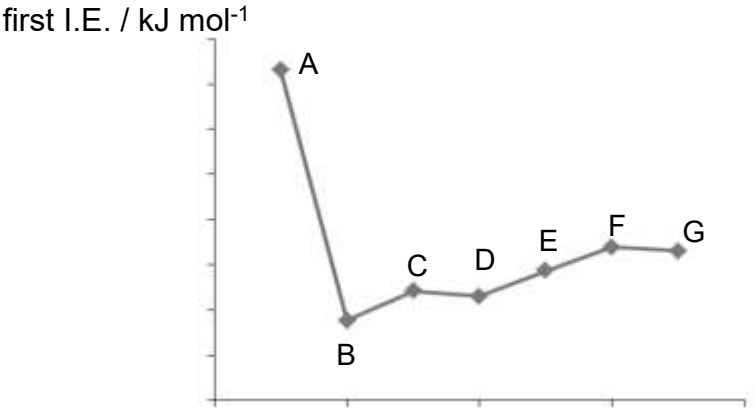
……..……..……..

……..……..……..

……..….[2]

[Total: 10]

4 The first ionisation energy of some consecutive elements in periods 2 and 3 are plotted.



(a) Explain why the first ionisation energy of element **A** is much higher than that of element **B**.

……

……

……[1]

(b) Write an equation to represent the second ionisation energy of element **A**.

……[1]

(c) Explain the increasing trend of the first ionisation energies from element **B** to **G**.

……

……

……[2]

(d) State which element is sulfur and explain your answer.

……

……[2]

(e) State the number of occupied principal quantum shells in one atom of sulfur in its ground state.

……[1]

[Total: 7]

5 **(a)** A student determined the concentration of ethanoic acid, CH_3COOH in a bottle of kitchen vinegar. He added 10 cm^3 of vinegar to a volumetric flask and followed by deionised water to make up the solution to 250 cm^3. The diluted vinegar was then poured into the burette.

On titration, 25 cm^3 of 0.0450 mol dm^{-3} $Ba(OH)_2$ was exactly neutralised by 25.45 cm^3 of the diluted vinegar.

(i) Write the balanced equation between CH_3COOH and $Ba(OH)_2$.

……[1]

(ii) Calculate the amount of CH_3COOH neutralised.

[2]

(iii) Calculate the amount of CH_3COOH in 250 cm^3 solution.

[1]

(iv) Determine the amount of CH_3COOH in 10 cm^3 of vinegar.

[1]

(b) Other than ethanoic acid, there are other non-cyclic compounds that have the same molecular formula, $C_2H_4O_2$.

Draw the skeletal formulae of three other non-cyclic isomers, with different functional groups from each other, which have this molecular formula.

[3]

(c) Ethanoic acid can be used to synthesis compound **W** which has the molecular formula $C_4H_8O_2$.

W decolourises the aqueous chlorine.

When 0.10 mol of **W** reacts with excess carboxylic acid under suitable conditions, 0.20 mol of water is formed, together with a neutral compound.

For each reaction mentioned above, identify and explain the type and number of each functional group present.

(i) reaction with aqueous chlorine

……..……..…..

……..……..…..

…….[1]

(ii) reaction with carboxylic acid

……..……..…..

……..……..…..

……..[2]

(d) Draw **two** possible skeletal formulae of **W** and name the type of isomerism they show.

Type of isomerism ……..[2]

[Total: 13]

6 Sunscreens are essential for protecting the skin from harmful ultraviolet (UV) radiation, which can cause sunburn, premature aging, and increase the risk of skin cancer. There are two main types of sunscreens based on how they work:

1. Physical sunscreens, containing TiO_2 or ZnO, are effective against UV A and UV B. They work as physical blockers sitting on the surface of the skin to reflect or scatter UV rays.
2. Chemical sunscreens are effective in blocking mostly UV B and some UV A. They work by using the organic compounds that absorb UV radiation.

(a) Nanoparticles of TiO_2 are preferred over bulk TiO_2 in sunscreen formulations while bulk TiO_2 is often used as a pigment in paints. Bulk TiO_2 particles scatter visible light, leading to a white, opaque appearance.

(i) Define what is meant by the term *nanoparticles*.

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……[1]

(ii) Describe the structure, bonding and properties, such as melting, solubility in water and conductivity, of bulk TiO_2.

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……[4]

(iii) Suggest two reasons why nanoparticles of TiO_2 are preferred over bulk TiO_2 in sunscreen formulations.

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……[2]

(b) Since 2021, Hawaii prohibits the sale, distribution, and offering of over-the-counter sunscreens containing oxybenzone and octinoxate — two chemical UV filters linked to coral bleaching and genetic damage in coral larvae.

On July 1, 2025, Hawaii introduced authorised state-funded dispensers of mineral-based sunscreen containing nanoparticles of ZnO or TiO_2 at all state beaches for distribution and reef protection.

By relating to the properties of nanoparticles, explain why the above measure may cause harm to marine life and the environment.

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……[3]

[Total: 10]

Section B

Answer **one** question from this section in the spaces provided.

7 Hydrogen stands out as a clean energy with strong potential to meet future energy needs sustainably. Producing hydrogen through electrolysis of water relies on the use of highly effective and durable catalysts. Advancing fuel cell technology is crucial in addressing key challenges related to the generation, conversion, and storage of clean energy.

(a) In the electrolysis of water, hydrogen gas is produced at the cathode and oxygen at the anode.

In acidic media:

Anode: $H_2O \rightarrow 2H^+ + ½\ O_2 + 2e^-$

Cathode: $2H^+ + 2e^- \rightarrow H_2$

Identify the types of reactions at the anode and cathode.

Anode ……

Cathode …… [2]

(b) Ammonia is now being explored as a hydrogen carrier for clean fuel. A hydrogen carrier is a substance that can store and release hydrogen when needed. It helps to safely transport and deliver hydrogen energy in a more practical form.

(i) In terms of the structure and bonding of hydrogen, suggest why hydrogen carrier is needed to safely transport and deliver hydrogen.

……

……

……[2]

(ii) Suggest why ammonia is emerging as one of the most promising hydrogen carriers.

……

……

……[2]

(iii) Traditional synthesis of ammonia uses the Haber Process:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H < 0$$

With reference to bond strength and activation energy, describe the type of bonding present in N_2 and explain why a catalyst is necessary in the Haber Process.

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……[2]

(iv) Using bond energies in the *Data Booklet*, calculate the enthalpy change for the Haber Process reaction in **7(b)(iii)**.

[2]

(v) Using the Boltzmann distribution, illustrate and explain how a catalyst affects the rate of the reaction.

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……[2]

(vi) Outline the mode of action of heterogeneous catalysis in the Haber Process.

Name the catalyst and include bond forming and bond breaking in your answer.

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…….....[4]

(c) The yield of ammonia is affected by pressure, temperature, and the removal of products.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H < 0$$

(i) Using Le Chatelier's Principle, explain how increasing pressure and decreasing temperature affect the position of equilibrium.

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…….....[2]

(ii) Comment on the temperature and pressure at which Haber Process operate industrially.

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……..[2]

[Total: 20]

8 Green industrial bleaching refers to environmentally friendly methods used to remove colour from materials like paper pulp or textiles, with minimal harm to the environment and human health.

(a) Historically, chlorine, Cl_2, was used in pulp and paper bleaching. While effective, it caused serious environmental issues.

(i) Suggest how the physical state of Cl_2 might influence its environmental impact.

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……...[2]

(ii) State and explain the trend in oxidising power of the halogens down Group 17.

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……...[2]

(b) In the pursuit of greener industrial bleaching processes, researchers are exploring the use of chlorine dioxide, ClO_2, due to lower environmental impact compared to chlorine gas.

(i) The standard enthalpy change of formation of $ClO_2(g)$ is +102 kJ mol^{-1}.

Define the standard enthalpy change of formation of $ClO_2(g)$.

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……...[1]

(ii) With reference to the standard enthalpy change of formation of $ClO_2(g)$, suggest why ClO_2 must be handled with care and how its thermodynamic properties influence its use in industrial processes.

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……..[3]

(iii) The reaction of chlorine dioxide in water is shown below:

$$2C\mathit{l}O_2(aq) + H_2O(l) \rightarrow HC\mathit{l}O_2(aq) + HC\mathit{l}O_3(aq) \quad \text{...equation 8.1}$$

Find the oxidation numbers to chlorine in each compound in the above equation.

$C\mathit{l}O_2$ .....

$HC\mathit{l}O_2$ .....

$HC\mathit{l}O_3$ ..... [2]

(iv) State and explain the type of reaction which occurs in equation 8.1.

……

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……[2]

(c) During aqueous bleaching, chlorous acid, $HC\mathit{l}O_2$, and chloric acid, $HC\mathit{l}O_3$, are produced. $HC\mathit{l}O_2$ exists transiently in solution and contributes to the oxidising environment during the bleaching process.

(i) Chlorous acid, $HC\mathit{l}O_2$, is a weak Brønsted-Lowry acid.

Define the term Brønsted-Lowry acid.

……

……

……[1]

(ii) Write an equation to represent how $HC\mathit{l}O_2$ reacts with water.

……[1]

(iii) Given that the value of K_a for the reaction of $HC\mathit{l}O_2$ with water is 1.1×10^{-2}, write the K_a expression based on your answer to **8(c)(ii)** and calculate the pH of a 0.100 mol dm^{-3} solution of $HC\mathit{l}O_2$.

[3]

(iv) $HClO_2$ and $HClO_3$ are both oxoacids of chlorine present in the bleaching process. Their K_a are 1.1×10^{-2} and 5.0×10^{2} respectively.

With reference to molecular structure of the oxoacids and oxidation state of chlorine, compare and explain the relative strengths of the two acids using their K_a values.

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……[3]

[Total: 20]

Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

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