Name:_____ Class:_____

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2025

CHEMISTRY **8873/02**
Higher 1
29 August 2025

Paper 2 **2 hours**

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A (60 marks)
Answer **all** the questions.

Section B (20 marks)
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	/15
	2	/16
	3	/11
	4	/12
	5	/6
Section B	6	/20
	7	/20
Penalty (delete accordingly)		
Missing/wrong **units** in final answer		**–1 / NA**
Total		/80

This document consists of **24** printed pages and **0** blank pages.

Section A

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

For Examiner's Use

1 A unknown metal sulfate has the formula **M**SO_4. The hydrated form of the metal sulfate has the formula **M**$SO_4.xH_2O$.

(a) Name the types of bonds that are present in the metal sulfate.

……

……

…… [2]

(b) When 6.24 g of the hydrated metal sulfate is strongly heated, thermal decomposition occurs. In addition to water, a solid oxide, **M**O, and a gaseous oxide are also produced. The solid oxide had a mass of 1.99 g.

The volume of the gaseous oxide produced was 600 cm^3 at r.t.p. A strongly acidic solution is produced when the gaseous oxide is dissolved in water.

(i) Write a balanced equation for the thermal decomposition of the hydrated metal sulfate.

…… [1]

(ii) Calculate the relative atomic mass of metal **M**.

Hence, suggest the identity of metal **M**.

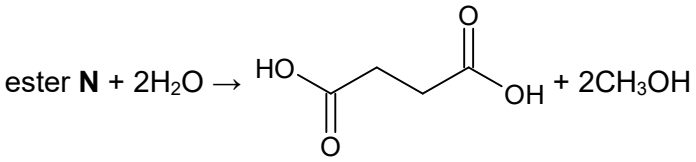
[3]

(iii) Using your answer in **(b)(ii)**, calculate the integer x in **M**$SO_4.xH_2O$.

[2]

For Examiner's Use

(c) The metal ion, $\mathbf{M}^{2+}$, can catalyse the hydrolysis of ester **N** into butanedioic acid and methanol as shown below.



butanedioic acid methanol

(i) State the number of σ bonds and π bonds in a molecule of butaedioic acid.

……... [1]

(ii) Draw the skeletal formula of ester **N**.

[1]

Butanedioic acid polymerises with 1,4–butanediamine to give nylon–4,4.

(iii) State the type of reaction and the catalyst required for the polymerisation process to occur.

……... [2]

(iv) Explain why clothing made from nylon–4,4 fibers are prone to creasing.

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……... [2]

(v) Suggest why nylon–4,4 is less of an environmental concern than HDPE when disposed in a landfill.

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……... [1]

[Total: 15]

For Examiner's Use

2 The artificially produced isotope of cobalt, $^{60}_{27}Co$, is used as a source of x-rays in medical radiotherapy.

(a) Write the full electronic configuration of cobalt ion, $^{60}_{27}Co^{2+}$.

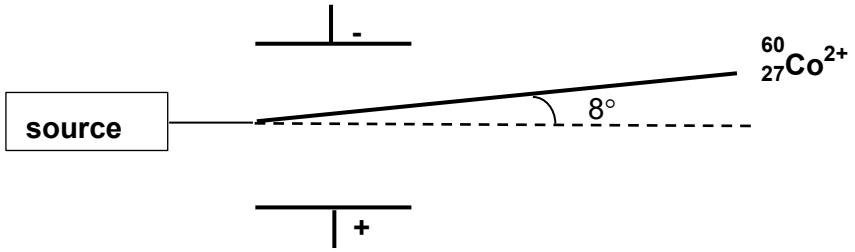
……..... [1]

(b) In an experiment, a sample of cobalt was vaporised, ionised and passed through an electric field. It was observed that a beam of $^{60}_{27}Co^{2+}$ gives an angle of deflection of 8º.

(i) Calculate the angle of deflection of $^{32}_{16}S^{2-}$ beam.

[1]

(ii) Sketch and label on the diagram below, how the beams of $^{32}_{16}S^{2-}$ would be deflected.



[1]

(c) Aqueous hydrogen peroxide, H_2O_2, oxidises tartrate ion, $C_4H_4O_6^{2-}$ in the presence of cobalt(II) chloride homogeneous catalyst in the equation given below.

$$5H_2O_2(aq) + C_4H_4O_6^{2-}(aq) \rightarrow 4CO_2(g) + 2OH^-(aq) + 6H_2O(l)$$

(i) State what is meant by the term *homogeneous* when it is applied to cobalt(II) chloride in the oxidation of tartrate ion by hydrogen peroxide.

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……... [1]

For Examiner's Use

(ii) By considering the structure of H_2O_2, suggest why the reaction between hydrogen peroxide and tartrate ion has a high activation energy.

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……... [1]

(iii) The reaction between hydrogen peroxide and tartrate ion is very colourful as pink Co^{2+} is oxidised to green Co^{3+} by hydrogen peroxide in the first step. This is followed by the reduction of Co^{3+} back to Co^{2+} when it reacts with the tartrate ion. The colour changes continues until all the reactants are used up.

Outline the mode of action of how cobalt(II) chloride catalyses the oxidation of tartrate ion by hydrogen peroxide.

State the species involved in each step of the reaction.

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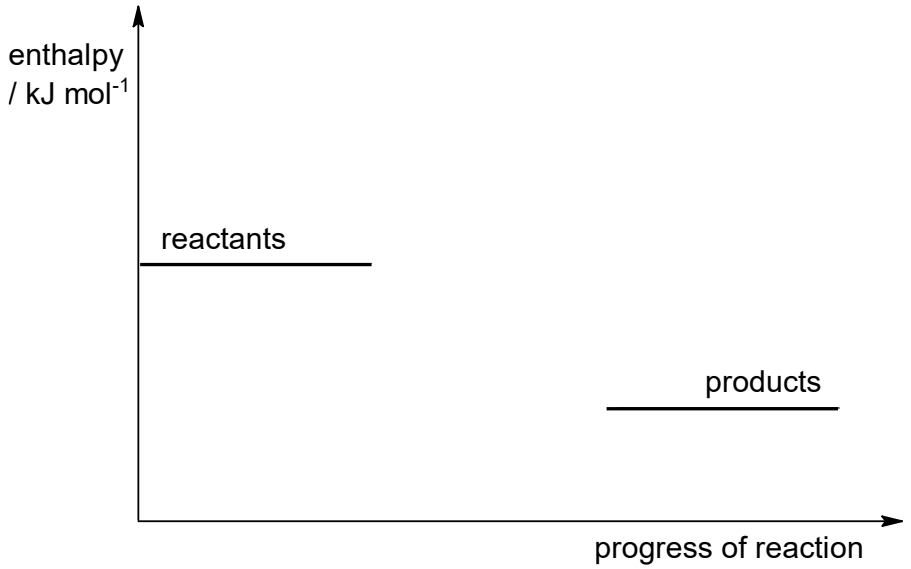
……... [2]

(iv) Hence, construct an energy profile diagram to show changes, if any, to the enthalpy change or activation energy **before and after** the addition of cobalt(II) chloride.



[2]

(d) Hydrogen peroxide and iodide ions react in acidic solution as shown.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

A series of experiments were conducted to determine the rate equation of the reaction.

(i) Use the following data to deduce the orders with respect to $[H_2O_2]$, $[I^-]$ and $[H^+]$, explaining your reasoning.

Experiment	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.05	0.05	0.05	1.25 x 10^{-3}
2	0.10	0.05	0.05	2.50 x 10^{-3}
3	0.10	0.20	0.05	1.00 x 10^{-2}
4	0.15	0.10	0.10	7.50 x 10^{-3}

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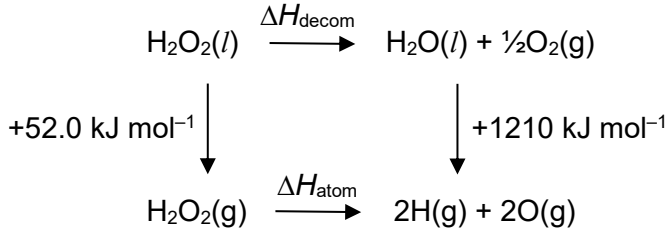
[3]

(ii) Using data from experiment 2, calculate the rate constant, k, for the reaction and state its units.

[1]

For Examiner's Use

(e) The following shows an energy cycle to determine the enthalpy change of decomposition of hydrogen peroxide.



(i) Define the term *bond energy*.

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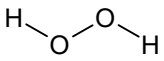
……... [1]

(ii) The structure of H_2O_2 is shown below.



Using data from the Data Booklet, calculate the enthalpy change of atomisation of $H_2O_2(g)$, ΔH_{atom}.

Hence, calculate the enthalpy change of decomposition of $H_2O_2(l)$, ΔH_{decom}.

[2]
[Total: 16]

For Examiner's Use

3 Magnesium, aluminium and silicon are elements in Period 3 of the Periodic Table.

All three elements react with oxygen to form stable oxides.

(a) Three unlabelled containers, each containing only one of the oxides, were reacted separately with aqueous NaOH and aqueous HC*l*.

Write balanced equations for any reaction that occured.

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…… [3]

(b) Aluminium rods can often be found on top of buildings as part of the lightning protection system. The lightning protection system provides a safe path for the energy to travel and hence minimising damage on buildings.

State and explain why aluminium is suitable for this role.

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…… [2]

(c) State and explain, in terms of bonding and structure, how the melting point of silicon dioxide differs from that of carbon dioxide.

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…… [3]

(d) Aluminium chloride reacts with ammonia to form an addition product.

$$NH_3 + AlCl_3 \rightarrow NH_3AlCl_3$$

(i) Draw the dot–and–cross diagram of the addition product.

[1]

(ii) Explain why ammonia is soluble in water.

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……... [2]

[Total: 11]

For Examiner's Use

4 **(a)** Compound **P** contains 51.9 % carbon, 9.73 % hydrogen and 38.4 % chlorine by mass.

When 0.100 mol of compound **P** is added to aqueous silver nitrate, 14.3 g of silver chloride is formed.

Compound **P** reacts with hot aqueous sodium hydroxide to give a compound that decolourise hot acidified potassium manganate(VII).

The reaction of compound **P** with hot ethanolic sodium hydroxide gives only one compound.

(i) Calculate the molecular formula of compound **P**.

[2]

(ii) Draw the displayed formula for compound **P**.

Explain your answer with reference to the reactions and the functional groups present in the compounds.

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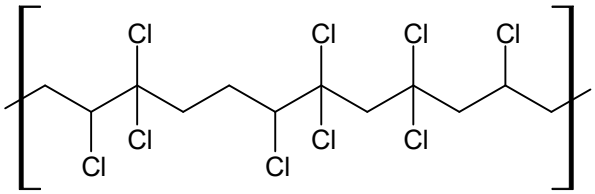
……... [4]

For Examiner's Use

(b) Cling wrap is a thin transparent plastic film usually used for sealing food items. It is a co-polymer formed from more than one monomer.

(i) The following following shows a segment of a polymer chain of cling wrap.



Draw the displayed formulae for the two monomers used to make cling wrap.

[2]

(ii) Suggest if cling wrap is a thermoplastic or thermoset polymer.

Using the structure of the polymer in **(b)(i)**, explain your answer.

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……... [2]

(iii) The minimum molar mass of a molecule of cling wrap is 1000 g mol^{-1}.

What is the minimum number of repeat units in a molecule of cling wrap.

[2]
[Total: 12]

For Examiner's Use

5 Carbon can exist in several different forms, including graphene and carbon nanotubes.

Graphene is colourless as the layer is just one atom thick. Graphene can be rolled into carbon nanotubes. Carbon nanotubes are black since they have a dimension larger than the nanoscale.

Carbon nanotubes are black because their structure is thicker and no longer on the nanoscale in all dimensions. A single carbon nanotube is extremely strong and has a very high tensile strength. However, materials made from many smaller carbon nanotubes arranged randomly are not as strong, as the alignment of the tubes is important for maximising strength.

In addition to their strength, carbon nanotubes are also excellent conductors of heat and electricity. Their unique combination of properties, small size, strength and conductivity, makes them useful in a wide range of applications such as energy storage, electronics, structural reinforcement, biomedical applications, and water treatment.

(a) Sketch a diagram to show the arrangement of carbon atoms in a carbon nanotube and use it to explain why carbon nanotubes are good electrical conductor.

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…… [2]

(b) Suggest why a single carbon nanotube would have high tensile strength.

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…… [1]

(c) Suggest why a material made of many smaller carbon nanotubes with their random arrangement would not be as strong.

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…… [1]

(d) Carbon nanotubes have a dimension which is larger than the nanoscale. Suggest why carbon nanotubes are still classed as nanomaterials.

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…… [1]

(e) Electronic devices could be made with a layer of graphene on the surface of the screen but **not** a layer of carbon nanotubes. Suggest why graphene could be used rather than carbon nanotubes.

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…… [1]

[Total: 6]

Section B

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

For Examiner's Use

6

(a) The table gives successive ionisation energies of element **X**.

	1st	2nd	3rd	4th	5th	6th	7th
I.E. / kJmol^{-1}	870	1800	3000	3600	5800	7000	13200

(i) State and explain the group that element **X** belongs to.

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……... [2]

(ii) **W** is the element before element **X** in the Periodic Table from period 3.

State and explain the difference in the first ionisation energy between element **X** and element **W**.

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……... [1]

(iii) State and explain the general trend of the first ionisation energy across the Period 3.

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……... [2]

(b) A bottle of tonic water contains carbon dioxide dissolved in water. A number of equilibria exist within a bottle of tonic water.

equilibrium **I** $CO_2(g) \rightleftharpoons CO_2(aq)$

equilibrium **II** $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

equilibrium **III** $H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

equilibrium **IV** $HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$

(i) Write a K_c expression for equilibrium **III**.

[1]

(ii) K_c for equilibrium **III** has a numerical value of 2.0×10^{-6}.

Calculate the concentration of $H^+(aq)$ ions in this equilibrium when the concentration of $H_2CO_3(aq)$ is 0.50 mol dm^{-3}.

[1]

(iii) Use the value calculated in **(ii)** to calculate the pH of the tonic water.

[1]

(iv) When the bottle cap is released and removed from a bottle of tonic water, bubbles of gas are seen escaping out of the liquid.

Suggest why this occurs. Explain your answer.

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……... [2]

(v) Methyl red is an indicator that is red in solutions below pH 4.2 and yellow in solutions above pH 6.3. This indicator is added to a bottle of tonic water immediately after it is opened.

The bottle is left open until no further changes is observed.

Suggest what would be observed during this time. Use the equilibria **I** to **IV** to explain your answer.

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……... [3]

(c) Atmospheric carbon dioxide levels have been increasing due to the burning of fossil fuels. A side effect is the acidification of water bodies as carbon dioxide dissolves in water to form carbonic acid, H_2CO_3.

(i) Write an equation, including state symbols, to represent the standard enthalpy of neutralisation of carbonic acid with sodium hydroxide, NaOH.

……... [1]

A student collected a 25.0 cm^3 sample of lake water. The initial temperature of the water was 24.8 °C. 25.0 cm^3 of 1.00 mol dm^{-3} NaOH, in excess, was added to the sample and the temperature was monitored over several minutes.

The highest temperature, corrected for heat loss, was 28.8 °C.

(ii) Given that the specific heat capacity of the mixture is 4.2 J g^{-1} K^{-1}, calculate the heat change for the neutralisation of carbonic acid.

Take the density of the mixture to be 1.0 g cm^{-3}.

[1]

(iii) Given that the standard enthalpy of neutralisation of carbonic acid is –42.7 kJ mol^{-1}, calculate the concentration of carbonic acid in the lake water.

[2]

(iv) Suggest why this method of determining the concentration of carbonic acid in the lake water is inaccurate.

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……... [1]

(d) Sodium bicarbonate, $NaHCO_3$, also known as baking soda, can be formed by reacting sodium carbonate, Na_2CO_3, with carbon dioxide.

$$Na_2CO_3(s) + CO_2(g) + H_2O(l) \rightarrow 2NaHCO_3(s)$$

Use the information below to calculate the standard enthalpy of reaction for the production of $NaHCO_3$ from Na_2CO_3.

compound	ΔH_f / kJ mol^{-1}
Na_2CO_3	–1131
$NaHCO_3$	–947
CO_2	–394
H_2O	–286

[2]
[Total: 20]

For Examiner's Use

7 Elements in Group 17 of the Periodic Table form many compounds with different properties.

(a) Describe what happens when A*l*C*l*$_3$ is added to water.

State the pH of the resultant solution.

Include an equation to aid your explanation.

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……..... [3]

(b) Upon heating, the hydrogen halides decompose to give hydrogen and the corresponding halogen.

Describe and explain how the thermal stability of the hydrogen halides differ from HC*l* to HI

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……..... [2]

(c) Fluorine and bromine are in Group 17 of the Periodic Table.

The K_a value for hydrofluoric acid, HF is 5.6 x 10^{-4} mol dm^{-3}.

The K_a value for hydrobromic acid, HBr, is much greater than 5.6 x 10^{-4} mol dm^{-3}.

Solutions of equal concentration of the two acids HF(aq) and HBr(aq) are prepared.

(i) Explain the meaning of the terms *acid*, *strong acid* and *weak acid*, in terms of BrØnsted-Lowry theory of acids.

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……... [3]

(ii) Suggest how the pH of these two solutions differ. Explain your answer in terms of the K_a values and the equilibrium positions in each solutions.

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……... [2]

(iii) 40.00 cm^3 of 0.100 mol dm^{-3} sodium hydroxide was added to the hydrofluoric acid in **(c)**.

Calculate the pH of the mixture at 25 °C.

[2]

(d) Sodium hypochlorite, NaOC*l*, is the active ingredient in bleach.

(i) When aqueous NaOC*l* is heated, it forms sodium chloride and sodium chlorate, $NaClO_3$.

State the type of reaction that happens when aqueous NaOC*l* is heated.

Explain your answer by stating the changes in oxidation state of the species involved.

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……... [3]

For Examiner's Use

The mass of NaOC*l* in bleach can be determined by first reacting the hypochlorite ion, OC*l*$^-$ with iodide to produce iodine.

$$OCl^- + I^- + 2H^+ \rightarrow I_2 + Cl^- + H_2O$$

The liberated iodine is then titrated with sodium thiosulfate, $Na_2S_2O_3$. $Na_2S_2O_3$ is added until the solution turns pale yellow.

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

Starch is then added as an indicator and the end–point of the reaction is reached when the blue–black colour of the starch–iodine complex is discharged.

A 25.0 cm^3 sample of an industrial bleach was first diluted to 1 dm^3. 25.0 cm^3 of the diluted bleach was pipetted into a conical flask and 10.0 cm^3 of 1.00 mol dm^{-3} aqueous iodide (in excess) was added.

The liberated iodine required 20.10 cm^3 of 0.200 mol dm^{-3} $Na_2S_2O_3$ for complete reaction.

(ii) Calculate the amount of iodine liberated by 25.0 cm^3 of the diluted bleach.

[1]

(iii) Hence, calculate the mass of NaOC*l* in the industrial bleach.

[3]

(iv) Explain why is starch required to be used as an indicator for the titration.

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……... [1]

[Total:20]

End of Paper

Additional answer space

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