Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 2

18 May 2026

Zone A morning | **Zone B** morning | **Zone C** morning

Session number

2 hours 30 minutes

Instructions to students

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

2226 – 4218

23 pages

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Sulfuric acid, H_2SO_4, is one of the highest-volume chemicals produced in the world.

(a) (i) The first step in the synthesis of sulfuric acid is to burn solid sulfur, S_8, to produce sulfur dioxide, SO_2.

$$S_8(s) + 8O_2(g) \rightarrow 8SO_2(g)$$

Determine the volume, in dm^3, of sulfur dioxide produced from 15.0 g of sulfur, at STP, using section 2 of the data booklet. [2]

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(ii) Calculate the new volume, in dm^3, of sulfur dioxide if the temperature changes to 25.0 °C, using the final volume from (a)(i).

Use sections 1, 2 and 4 of the data booklet.

If you did not obtain an answer for (a)(i) use 15.0 dm^3, although this is not the correct answer. [1]

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(This question continues on the following page)

(Question 1 continued)

(b) Sulfur dioxide is converted to sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(i) Identify the oxidation state of sulfur in both compounds. [1]

Compound	Oxidation state of sulfur
SO_2	. . . . .
SO_3	. . . . .

(ii) State the equilibrium constant expression, *K*, for this reaction. [1]

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(iii) State, with a reason, the effect of increasing the temperature on the value of the equilibrium constant, *K*. [1]

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -198\,kJ\,mol^{-1}$$

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(iv) Discuss the effect of decreasing the volume of the system on the position of equilibrium and the value of *K*. [2]

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Position of equilibrium: . . . . . .

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Value of *K*: . . . . . .

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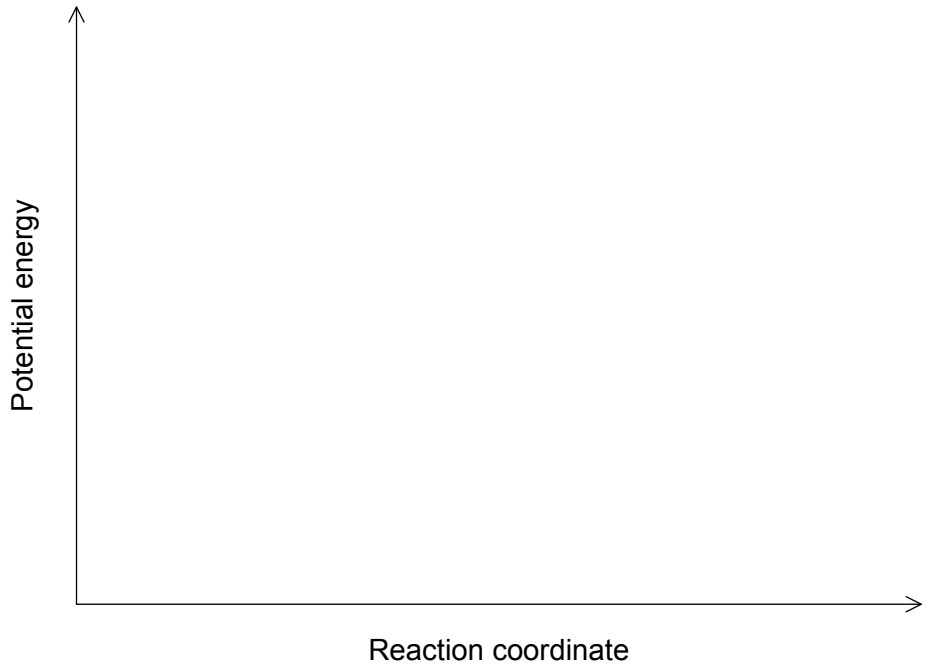
will not be marked.

(Question 1 continued)

(c) The final synthetic step can be summarized as:

$$H_2O(l) + SO_3(g) \rightarrow H_2SO_4(aq) \qquad \Delta H^{\ominus} = -101\,kJ\,mol^{-1}$$

(i) Sketch an energy profile for the overall reaction indicating the $\Delta H^{\ominus}$ and the activation energy. [2]



(ii) Describe the types of bonding found in the concentrated aqueous sulfuric acid product. [2]

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(This question continues on the following page)

(Question 1 continued)

(d) Sulfuric acid, H_2SO_4, is strong, while sulfurous acid, H_2SO_3, is weak.

(i) Outline the difference between a strong and a weak acid. [1]

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(ii) Deduce the Lewis formula and the molecular geometry for the sulfite ion, SO_3^{2-}. [2]

Lewis formula:

Molecular geometry: . . . . . .

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(This question continues on the following page)

(Question 1 continued)

(iii) State the hybridization of the sulfur atom in the sulfite ion. [1]

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(iv) Explain the stability of the sulfite ion based on its Lewis formula. [2]

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(This question continues on the following page)

(Question 1 continued)

(e) Sulfuric acid is used as the electrolyte in a lead-acid cell. Lead, Pb, is the anode in the cell.

$$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq) \qquad E^\ominus = -0.36\,V$$

$$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l) \qquad E^\ominus = 1.69\,V$$

(i) Deduce the overall reaction for the cell. [1]

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(ii) Calculate the cell potential, $E^\ominus$cell. [1]

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(iii) Calculate the standard change in Gibbs energy, $\Delta G^\ominus$, in kJ mol^{-1}, of the cell reaction.

Use sections 1 and 2 of the data booklet.

If you did not obtain an answer for (e)(ii) use 1.25 V, although this is not the correct answer. [2]

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(Question 1 continued)

(f) Energy can be produced by a fuel cell with hydrogen gas at the anode and oxygen gas at the cathode with a base as the electrolyte.

(i) Deduce the half-equations for the electrode reactions in this fuel cell. [2]

Anode half-equation: . . . . . .

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Cathode half-equation: . . . . . .

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(ii) Hydrogen produces a line emission spectrum with **four** lines in the visible region.

Discuss **two** properties of the current atomic model supported by the line emission spectrum of hydrogen. [2]

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(iii) Determine the energy of a photon, in J, emitted from hydrogen with a wavelength of 434.0 nm.

Use sections 1, 2 and 3 of the data booklet. [2]

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2. Potassium, K, is a reactive metal.

(a) (i) State the number of protons, electrons and neutrons in $^{39}K^{+}$. [2]

Protons:	. . . . .
Electrons:	. . . . .
Neutrons:	. . . . .

(ii) State the full electron configuration for $^{39}K^{+}$. [1]

. . . . . .

(iii) The relative atomic mass, A_r, of K is 39.10.

Isotope	Mass	Percent abundance
^{x}K		93.26 %
^{41}K	40.96	6.730 %

Determine the relative mass of the first isotope of K to four significant figures, showing your work. [2]

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(This question continues on the following page)

(Question 2 continued)

(b) (i) Explain why K has a lower first ionization energy than calcium, Ca. [2]

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(ii) Outline why K has a lower electronegativity than sodium, Na. [1]

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(iii) Explain why sulfur, S, has a lower first ionization energy than phosphorous, P. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) (i) Write the equation for the reaction of K with water, H_2O, including state symbols. [2]

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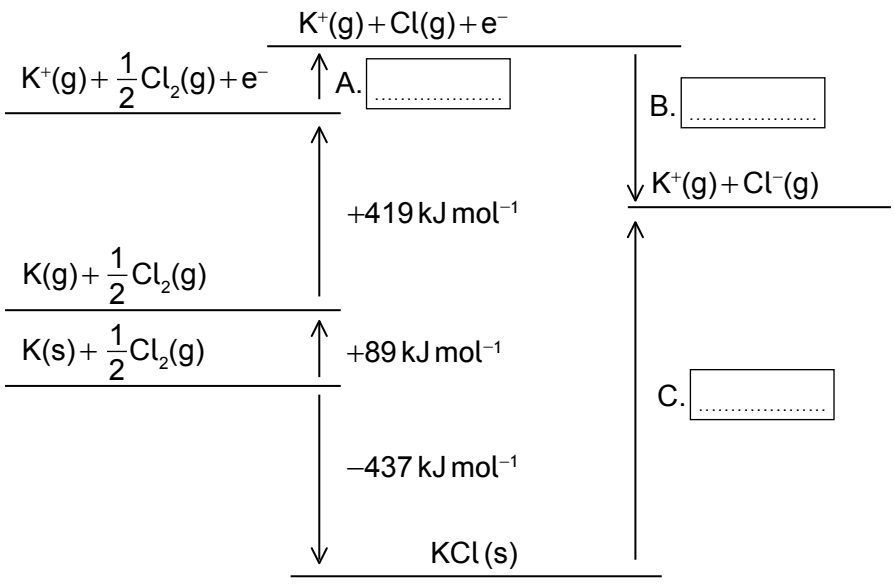
(ii) Describe the type of bonding in K and H_2O and how the valence electrons in each produce these types of bonds. [2]

	Type of bonding	How valence electrons produce bonds
K	. . . . .	. . . . .
H_2O	. . . . .	. . . . .

(d) Potassium also forms compounds with halogens such as chlorine, Cl.

Annotate the Born–Haber cycle for potassium chloride, KCl, with the correct values.

Use sections 9 and 12 of the data booklet. [3]



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(Question 2 continued)

(e) Transition elements have unique properties.

(i) State **two** properties of transition elements other than the formation of coloured compounds. [2]

Property 1: . . . . . .

Property 2: . . . . . .

(ii) Explain why transition element compounds are coloured. [3]

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3. Propane, $CH_3CH_2CH_3$, is a common fuel.

(a) (i) Determine the enthalpy of combustion of propane, in $kJ\,mol^{-1}$, using table 12 in the data booklet. [3]

$$CH_3CH_2CH_3(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

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(ii) Calculate the mass, in g, of carbon dioxide, CO_2, produced when 25.0 g of propane react with 95.0 g of oxygen, showing your work. [3]

$$CH_3CH_2CH_3(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

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(iii) The enthalpy of combustion for propane in table 14 of the data booklet is $-2219\,kJ\,mol^{-1}$.

Outline why there is a difference between the value in this table and the one obtained in (a)(i). [1]

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(This question continues on the following page)

(Question 3 continued)

(b) Propane reacts with bromine, Br_2, to form 2-bromopropane.

(i) Explain, using equations, the initiation step and **two** propagation steps for this reaction. [3]

Initiation: . . . . . .

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Propagation: . . . . . .

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(ii) 2-Bromopropane reacts with aqueous sodium hydroxide, NaOH(aq), to form propan-2-ol, $CH_3CH(OH)CH_3$.

Suggest the mechanism for this reaction, giving your reason, based on the structure of 2-bromopropane. [2]

Mechanism: . . . . . .

Reason: . . . . . .

(iii) The product was analysed by ^1H NMR.

Predict the number and relative areas of signals for propan-2-ol. [2]

Number of signals: . . . . . .

Relative areas: . . . . . .

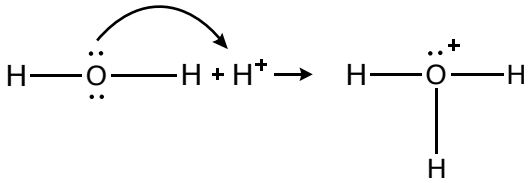
(This question continues on the following page)

(Question 3 continued)

(c) Propan-2-ol can also form by reacting propene with water in the presence of an acid catalyst.

$$CH_2=CHCH_3(g) + H_2O(l) \rightarrow CH_3CH(OH)CH_3(aq) \qquad \Delta H^{\ominus} = -126\,kJ\,mol^{-1}$$

(i) The first step of the mechanism for the formation of propan-2-ol is the protonation of water.



Sketch the mechanism for the formation of this product using curly arrows. [4]

(ii) Explain why increasing the temperature would increase the rate of this reaction. [2]

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(This question continues on the following page)

(Question 3 continued)

(iii) Explain the relative solubility of propan-2-ol and propene in water. [2]

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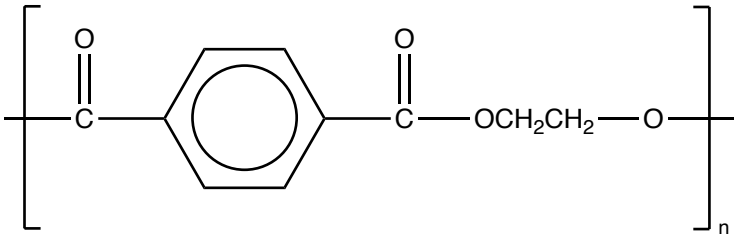
(iv) Propene can also form a polymer.

Draw a section of the polymer with three repeating units. [1]

(v) Dacron is a polymer formed by a condensation reaction.



Draw the structural formulas of the two monomers that form Dacron. [2]

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will not be marked.

(Question 3 continued)

(d) Propan-2-ol will react with acidified potassium dichromate, $K_2Cr_2O_7$, which is an oxidizing agent.

(i) State the name of the product of this reaction. [1]

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(ii) Explain how infrared spectroscopy could be used to distinguish between propan-2-ol and the product in (d)(i), referring to both structures.

Use section 20 of the data booklet. [2]

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4. Potassium hydroxide, KOH, can neutralize organic acids.

(a) Calculate the pH of a 0.0685 mol dm^{-3} solution of potassium hydroxide. [2]

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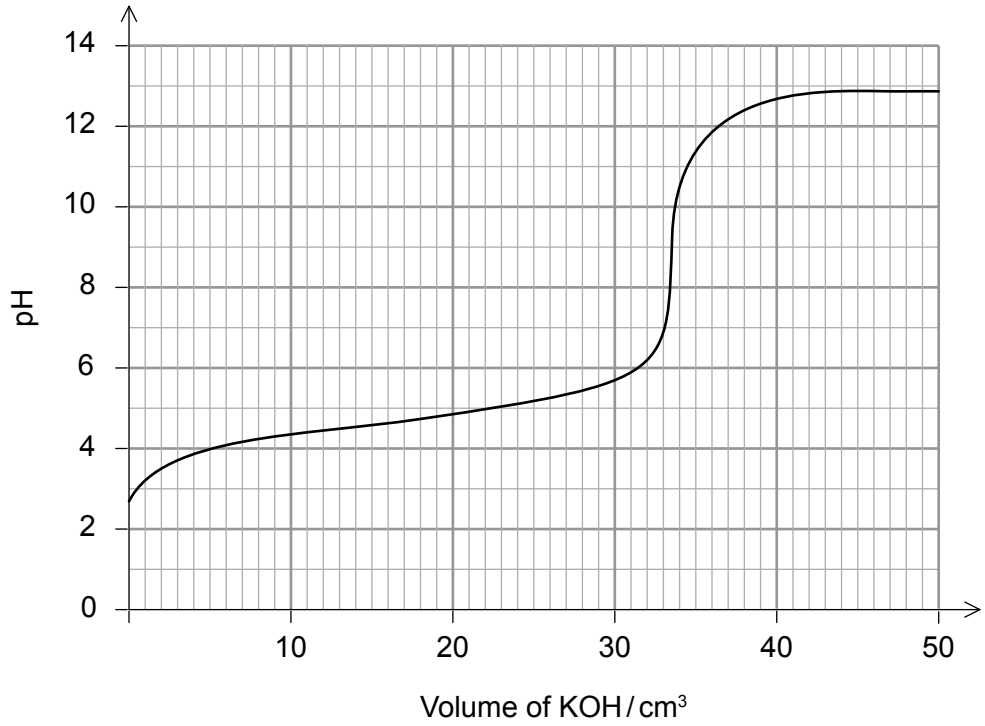
(b) A sample of the potassium hydroxide solution is gradually added to 50.0 cm^3 of an aqueous solution of an unknown organic acid, producing the following pH curve.



Calculate the concentration of the unknown organic acid. [2]

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(Question 4 continued)

(c) State, with a reason, which indicator would be appropriate for this titration, using section 18 of the data booklet. [1]

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(d) Suggest two different mixtures which would produce a buffer solution from the organic acid. [2]

Mixture 1: . . . . . .

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Mixture 2: . . . . . .

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5. Nitrogen(II) oxide reacts with hydrogen.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The data shows how the rate of reaction varies as the reactant concentrations change.

Experiment	**Initial [NO] (g) / mol dm^{-3}**	**Initial [H_2] (g) / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.100	0.100	2.53×10^{-6}
2	0.100	0.200	5.05×10^{-6}
3	0.200	0.100	10.10×10^{-6}
4	0.300	0.100	22.80×10^{-6}

(a) Determine the order of reaction with respect to NO and with respect to H_2. [2]

Reactant	**Order of reaction**
NO	. . . . .
H_2	. . . . .

(b) Deduce the rate equation for the reaction. [1]

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(c) Calculate the rate constant using the data from experiment 1 and include its units in the your answer. [2]

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