Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

19 May 2025

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

1 hour 30 minutes

Instructions to candidates

- 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 **[50 marks]**.

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

1. Phenolphthalein is an acid–base indicator.
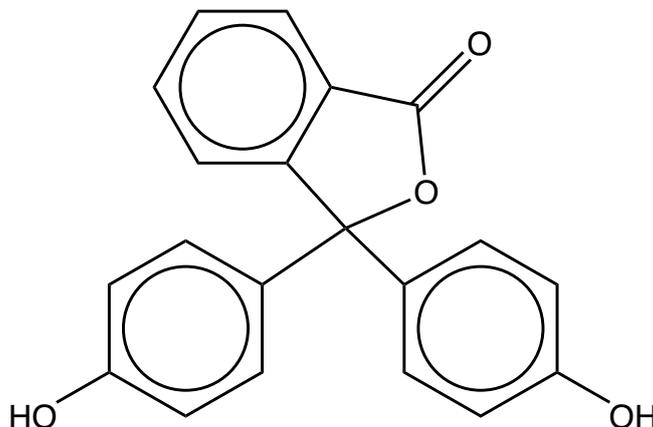
Phenolphthalein

(a) Determine the molecular and empirical formulas of phenolphthalein. [2]

Molecular formula: ....

....

Empirical formula: ....

....

(b) State an equation for phenol, C_6H_5OH, when it is acting as an acid. [1]
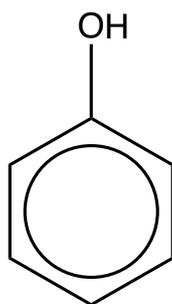
Phenol

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2. Models are useful for explaining characteristics and predicting outcomes.

State and explain **two** properties of a liquid using the kinetic molecular theory model. [2]

Property 1: ....

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Property 2: ....

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Turn over

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Answers written on this page
will not be marked.

3. Ammonia is produced industrially using the reversible reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(a) Calculate the equilibrium constant, K, when $30.0\,mol\,N_2$, $40.0\,mol\,H_2$ and $6.17\,mol\,NH_3$ are at equilibrium in a $55.0\,dm^3$ reaction container at a temperature of $450\,°C$. [3]

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(b) The volume of the reaction container of the mixture at equilibrium is suddenly decreased.

Sketch the graph of the concentration of nitrogen versus time on the axes below until after the new equilibrium is established at a constant temperature. [3]

$[N_2]$

Volume of reaction container decreased

New equilibrium established

Time

Turn over
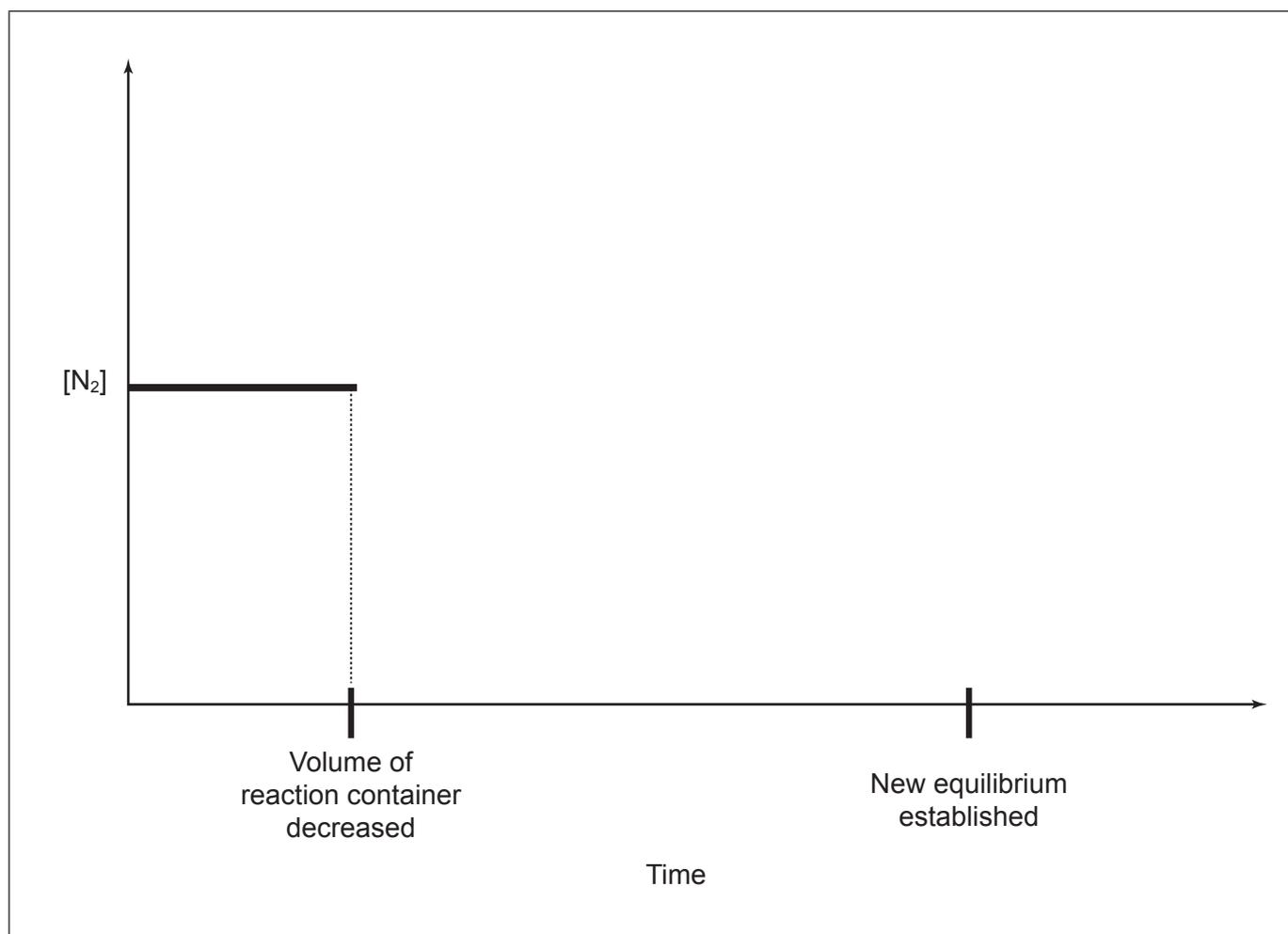
4.   Halogenoalkanes are used as refrigerants and solvents.

(a)   State the International Union of Pure and Applied Chemistry (IUPAC) name of
      substance **X**, $CH_3CHBrC(CH_3)_3$.   [1]

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(b)   Calculate the percentage by mass of hydrogen in substance **X** to **four** significant
      figures. Use section 7 of the data booklet.   [2]

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(c)   Draw a structural isomer of molecule **X**.   [1]

(d)   Substance **X** undergoes nucleophilic substitution with a hydroxide nucleophile.

(i)   Describe the movement of electron pairs during the reaction using curly arrows.   [2]

(This question continues on the following page)

(Question 4 continued)

(ii) Contrast homolytic and heterolytic fission. [2]

Homolytic fission: . . . .

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Heterolytic fission: . . . .

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(iii) Explain, using collision theory, how an increase in temperature increases the reaction rate. [3]

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5. Ethyne, C_2H_2, is hydrogenated to form ethane.

$$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$$
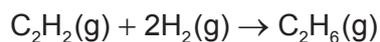
(a) $140.0\,cm^3$ of ethyne is reacted with $160.0\,cm^3$ of hydrogen in a container at $420\,K$ and $1.00 \times 10^5\,Pa$. Ethane is the only product.

Determine the maximum possible volume of ethane formed under these conditions of temperature and pressure. [2]

(b) Determine the total volume of gas present in the container at the end of the reaction under the same conditions of temperature and pressure. [2]

6. A lithium-ion battery consists of lithium ions on lithium-graphite (LiC_6) and lithium-cobalt oxide ($LiCoO_2$) in an electrolyte.

Lithium-ion battery
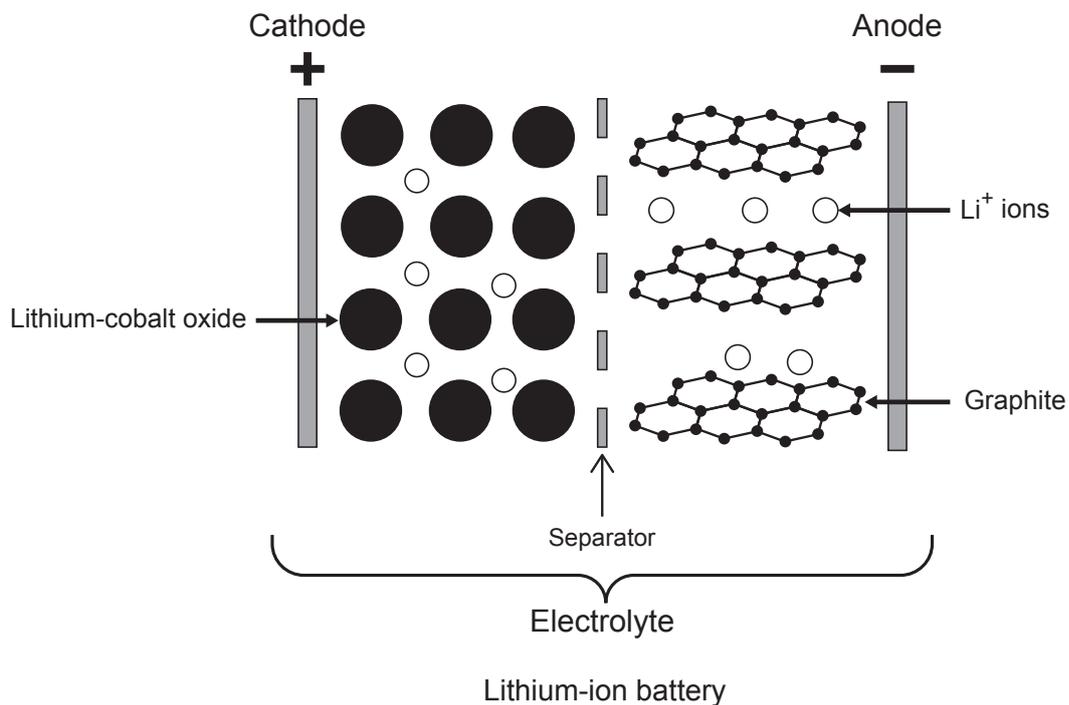
(a) The lithium ions are produced at the anode from the lithium atoms embedded in graphite.

(i) State a half-equation for the reaction occurring at the anode during discharge. [1]

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(Question 6 continued)

(ii) The lithium-ion battery is rechargeable. Annotate the diagram below to show the direction of the flow of electrons in the wire while the battery is recharging.   [1]
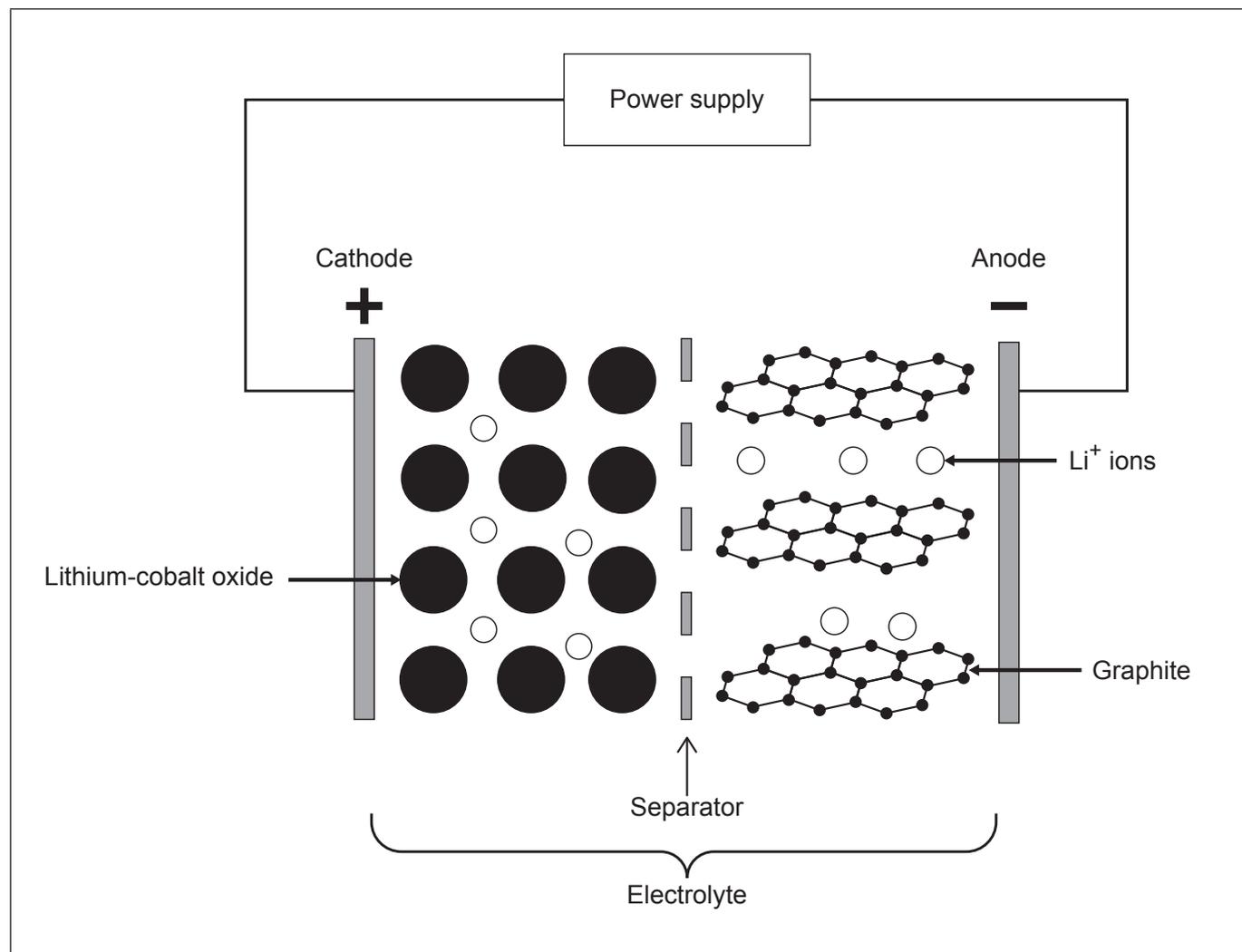
(b) Suggest why solar panels are often connected in parallel with lithium-ion batteries.   [1]

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7. Sulfur dioxide, SO_2 is involved in the formation of acid rain.

(a) (i) State the electron configuration for S. [1]

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(ii) Draw the Lewis formula of SO_2. [1]

(iii) Deduce the electron domain geometry and molecular geometry of SO_2. [2]

Electron domain geometry: ....

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Molecular domain geometry: ....

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(iv) Explain the polarity of the SO_2 molecule. [2]

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(This question continues on the following page)

(Question 7 continued)

    (b)   Sulfur dioxide reacts with rain water and oxygen to form sulfuric acid, H_2SO_4.

        (i)   State an equation for this reaction including the state symbols. [2]

        (ii)   Explain, with reference to the oxidation states of **two** elements, why this is
             a redox reaction. [2]

        (iii)   Describe the effect of acid rain on buildings that are made of limestone
             (calcium carbonate). Include a chemical equation in your answer. [2]

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(Question 7 continued)

(c)   Sulfuric acid can form hydrogen bonds with water.

Annotate the diagram to show the formation of hydrogen bonds between molecules of H_2SO_4 and water. Use a dotted line to represent the hydrogen bond.   [1]
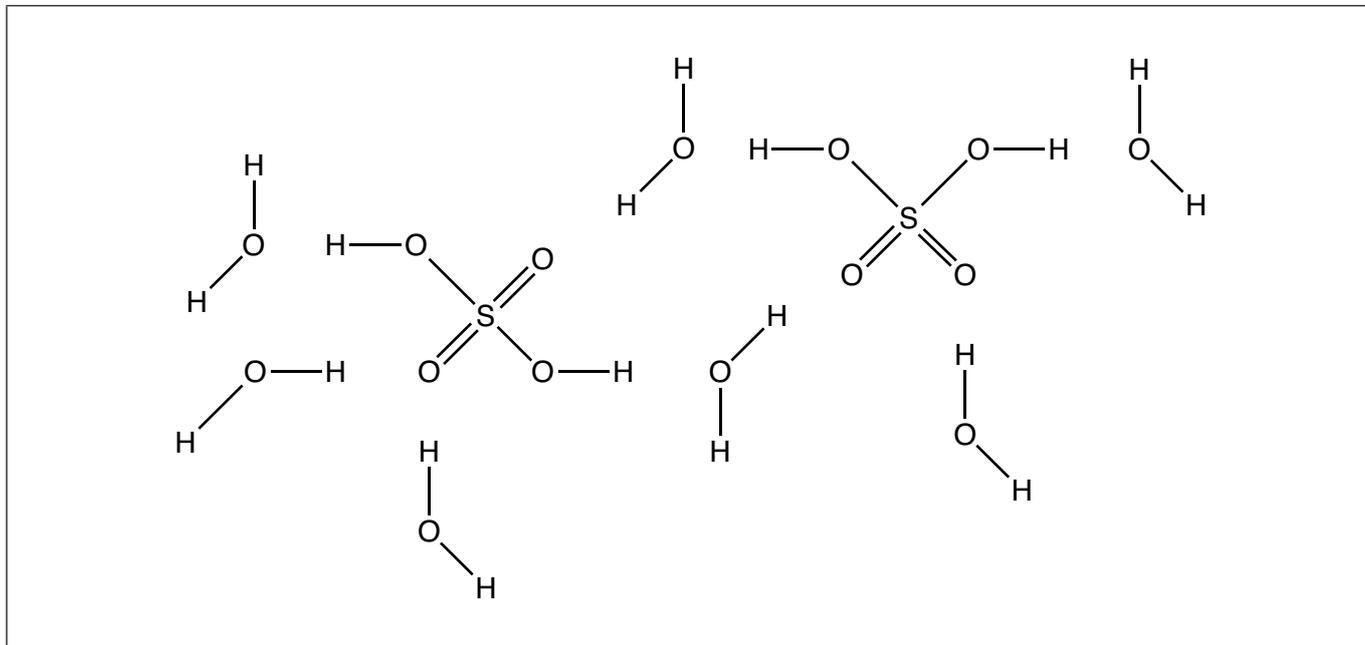
(d)   Discuss the following data in terms of the bonding **and/or** intermolecular forces in each substance: [3]

Substance	Melting point / K
Silicon	1683
Poly(ethene)	393

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8. Ethanol is a biofuel that can be made from glucose. Glucose is formed by the biological fixation of carbon through photosynthesis.

(a) (i) State the equation for photosynthesis. [1]

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(ii) Outline **two** advantages of using ethanol as a fuel instead of gasoline (petrol). [2]

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(b) Calculate the increase in temperature of a sample of $500.0\,cm^3$ of water heated by the combustion of $4.00\,g$ of ethanol. Use sections 2 and 14 of the data booklet. [2]

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