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# Chemistry Higher level Paper 2

19 May 2025

Zone A morning | Zone B morning | Zone C morning

Candidate session number

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2 hours 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 **[90 marks]**.



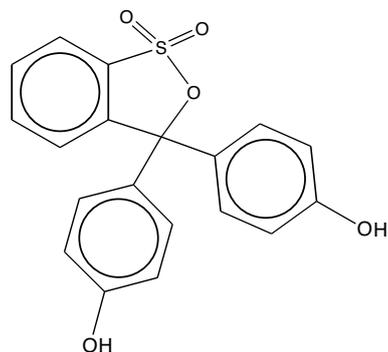
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Answers written on this page  
will not be marked.

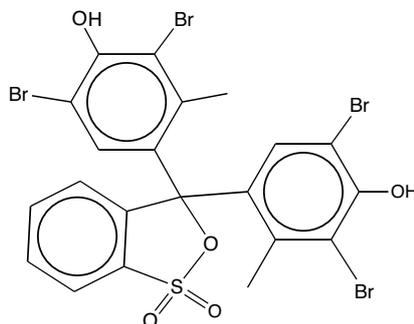


Answer **all** questions. Answers must be written within the answer boxes provided.

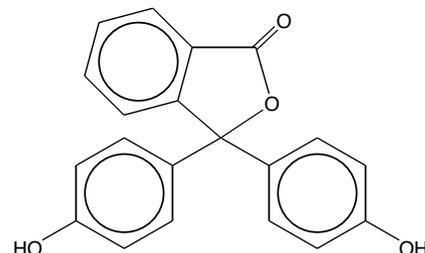
1. Phenol red, bromocresol green and phenolphthalein are acid-base indicators.



Phenol red



Bromocresol green



Phenolphthalein

(a) The indicators have three benzene rings in their structure.

(i) State a functional group, other than the phenyl group, that the three indicators have in common. [1]

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(ii) Deduce the colour **absorbed** by the following indicators in **alkaline** conditions. Use sections 15 and 18 of the data booklet. [2]

Phenol red: .....

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Bromocresol green: .....

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

Molecular formula: .....

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Empirical formula: .....

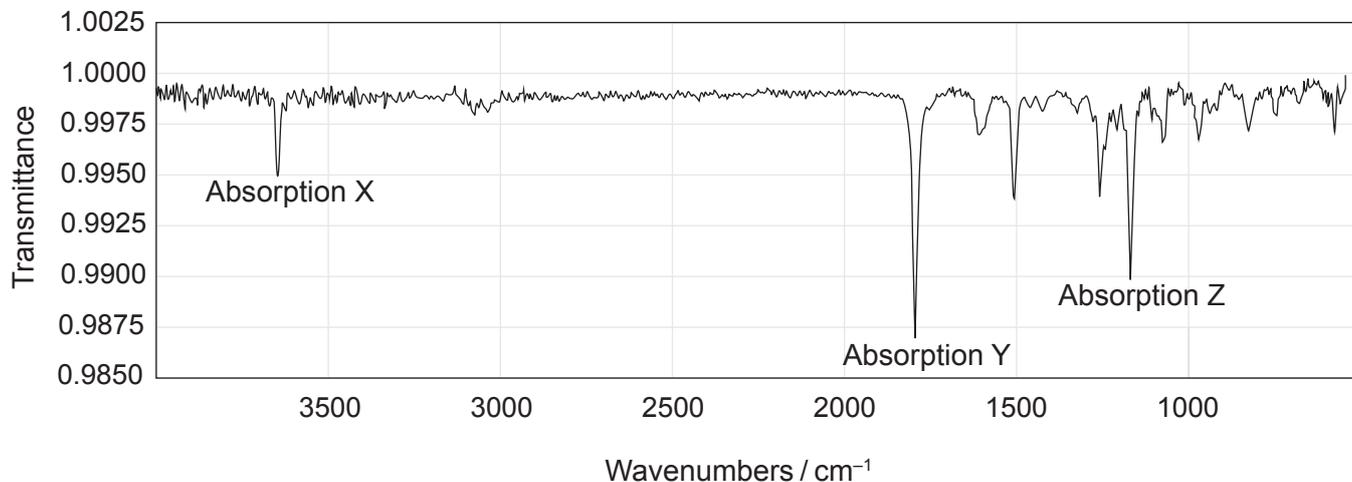
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(Question 1 continued)

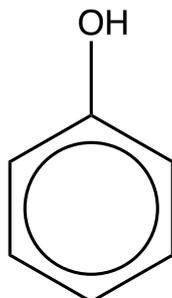
- (ii) State the bonds responsible for the absorptions labelled X, Y and Z in the infrared (IR) spectrum of phenolphthalein shown below. Use section 20 of the data booklet. [3]



[Source: Used with permission. © United States of America as represented by the Secretary of Commerce.]

Absorption X: .....  
Absorption Y: .....  
Absorption Z: .....

- (c) State an equation for phenol, C<sub>6</sub>H<sub>5</sub>OH, when it is acting as an acid. [1]



Phenol

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(This question continues on the following page)



**(Question 1 continued)**

(d) Explain how the indicator HInd, that is a weak acid, shows changes in pH using an equation.

[2]

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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: .....

.....  
.....



3. Ammonia is produced industrially using the reversible reaction.



- (a) (i) Calculate the equilibrium constant,  $K$ , when 30.0 mol  $\text{N}_2$ , 40.0 mol  $\text{H}_2$  and 6.17 mol  $\text{NH}_3$  are at equilibrium in a 55.0 dm<sup>3</sup> reaction container at a temperature of 450 °C. [3]

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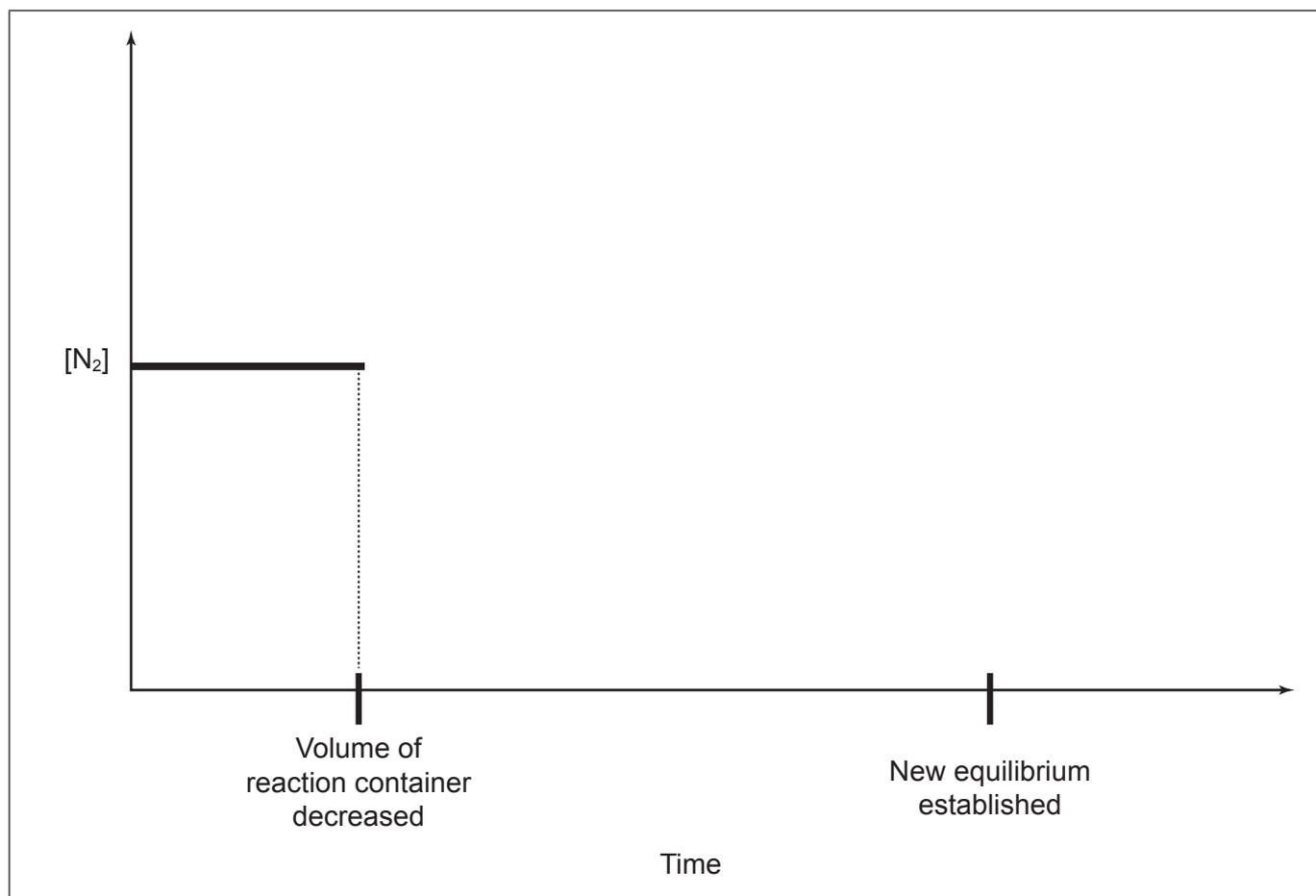
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- (ii) The volume of the reaction container of the mixture at equilibrium is suddenly decreased.

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]



(This question continues on the following page)



**(Question 3 continued)**

- (iii) Calculate the standard change in Gibbs energy,  $\Delta G^\ominus$ , for this reaction at 450 °C, stating its units. Use your answer to part (a)(i) and section 1 of the data booklet. [2]

If you did not obtain an answer to part (a)(i) then use the value 0.200, although this is not the correct answer.

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- (b) (i) Outline how ammonia acts as a Lewis base when it forms the complex ion  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$ . [1]

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- (ii) Determine the pH of a 0.350 mol dm<sup>-3</sup> solution of ammonia. Use section 1 of the data booklet. [3]

$\text{p}K_b(\text{NH}_3) = 4.75$

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4. Halogenoalkanes are used as refrigerants and solvents.

(a) State the International Union of Pure and Applied Chemistry (IUPAC) name of substance **X**,  $\text{CH}_3\text{CHBrC}(\text{CH}_3)_3$ .

[1]

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(b) Draw the optical isomers of substance **X**, showing the three-dimensional orientation of groups around the chiral centre.

[2]

(c) 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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(d) The reaction between substance **X** and sodium hydroxide depends on their concentrations.

(i) Explain the mechanism of the reaction, using curly arrows to represent the movement of electron pairs.

[4]

(This question continues on the following page)



**(Question 4 continued)**

(ii) Explain why  $\text{CH}_3\text{CHIC}(\text{CH}_3)_3$  reacts faster than  $\text{CH}_3\text{CHBrC}(\text{CH}_3)_3$ . [2]

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

Homolytic fission: .....

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Heterolytic fission: .....

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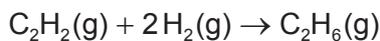
(e) Draw a structural isomer of molecule **X**. [1]

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5. Ethyne,  $C_2H_2$ , is a useful raw material in the synthesis of organic compounds.

- (a) (i) Calculate the standard enthalpy change, in  $kJ\ mol^{-1}$ , of the complete hydrogenation of ethyne to produce ethane. Use section 14 of the data booklet. [2]



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- (ii) Calculate the temperature at which this reaction is no longer spontaneous. [2]

Use your answer to part (a)(i) and section 1 of the data booklet.

The standard entropy change of this reaction is  $\Delta S^\ominus = -233\ JK^{-1}\ mol^{-1}$ .

If you did not obtain an answer to part (a)(i) then use the value  $-80.0\ kJ\ mol^{-1}$ , although this is not the correct answer.

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(This question continues on the following page)



**(Question 5 continued)**

- (b)  $140.0\text{ cm}^3$  of ethyne are reacted with  $160.0\text{ cm}^3$  of hydrogen in a container at  $420\text{ K}$  and  $1.00 \times 10^5\text{ Pa}$ . Ethane is the only product.

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

[2]

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- (c) (i) Draw the Lewis formula of  $\text{C}_2\text{H}_2$ .

[1]

- (ii) State the hybridization of the carbon atom in  $\text{C}_2\text{H}_2$ .

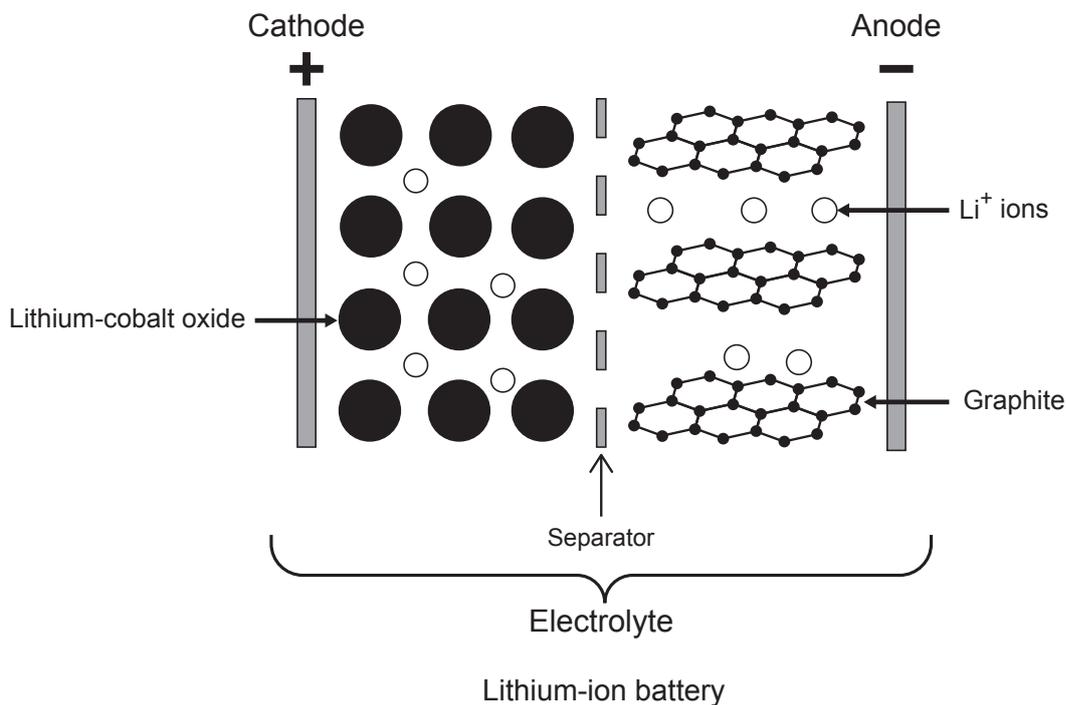
[1]

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6. A lithium-ion battery consists of lithium ions on lithium-graphite ( $\text{LiC}_6$ ) and lithium-cobalt oxide ( $\text{LiCoO}_2$ ) in an electrolyte.



- (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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- (ii) Comment on the sign and value of the standard reduction potential of lithium that make it suitable to use in the battery. Use section 19 of the data booklet. [2]

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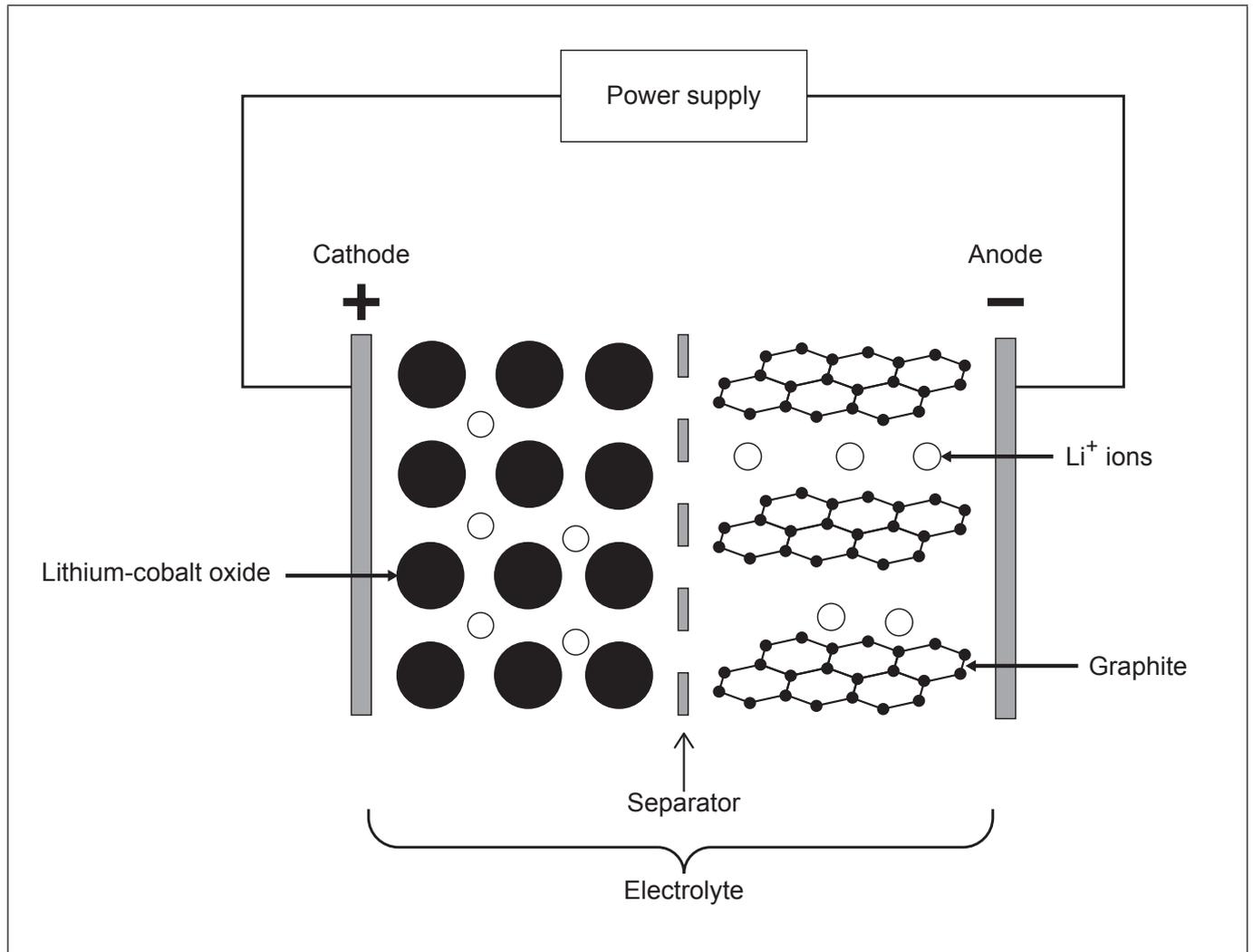
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(Question 6 continued)

(b) 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]



(c) Suggest why solar panels are often connected in parallel with lithium-ion batteries. [1]

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(This question continues on page 15)



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**(Question 6 continued)**

- (d) A charge of 1000.0 C passes through a lithium-ion battery during discharge. Determine the number of lithium ions released at the anode. Use section 2 of the data booklet. [2]

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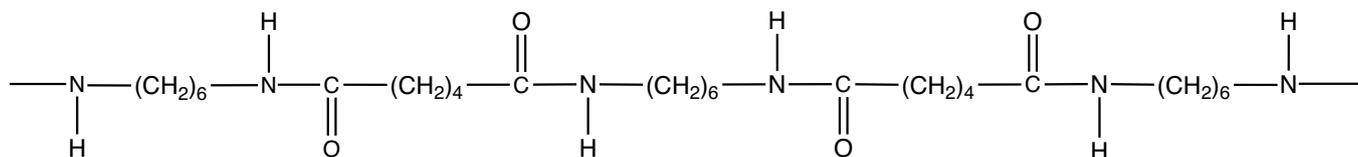
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7. Nylon 6,6 is a polyamide used in many things, such as fishing lines.

**A section of the polymer chain of nylon 6,6**



(a) Nylon 6,6 is formed by condensation polymerisation.

Deduce the structures of the two monomers that form the polyamide nylon 6,6.

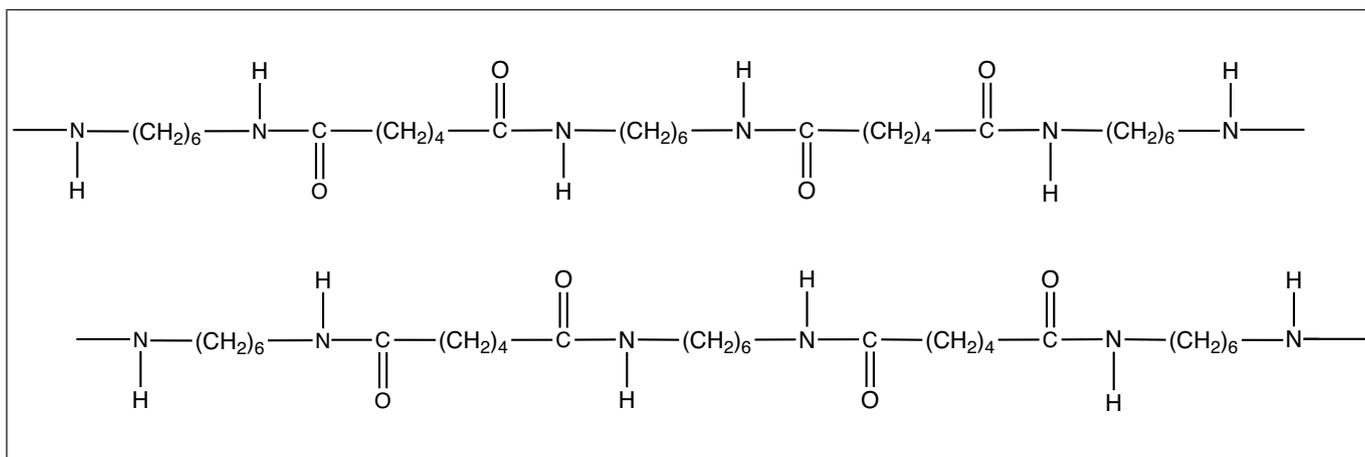
[2]

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(b) (i) The strength of nylon 6,6 is due to the hydrogen bonding between the polymer chains.

Annotate the diagram to show a hydrogen bond between the sections of the polymer chains. Use a dotted line to represent the hydrogen bond.

[1]



(ii) Outline how a hydrogen bond is formed.

[2]

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(This question continues on the following page)



**(Question 7 continued)**

- (c) 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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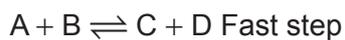
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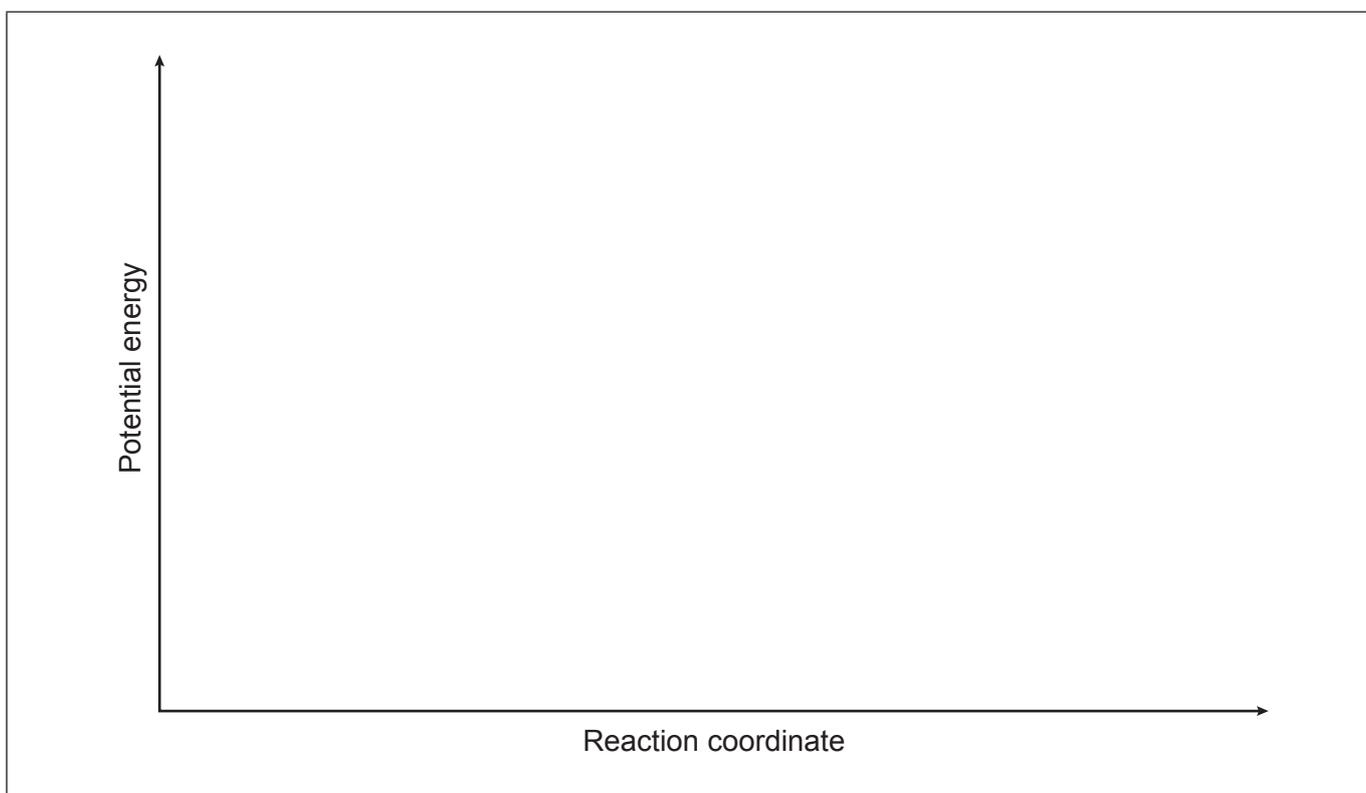
8. The mechanism of an exothermic reaction between A and B consists of two steps.



(a) (i) State the products of the reaction. [1]

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(ii) Sketch the energy profile for this reaction. Include labels for reactants, products, transition state(s) and intermediate(s). [3]



(iii) Deduce the rate equation of the reaction. [2]

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**(Question 8 continued)**

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

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

(a) State the equation for photosynthesis.

[1]

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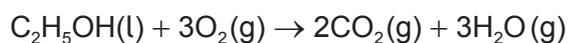
(b) (i) Outline **two** advantages of using ethanol as a fuel instead of gasoline (petrol).

[2]

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(ii) Calculate the enthalpy change for the combustion of ethanol in  $\text{kJ mol}^{-1}$ . Use section 12 of the data booklet.

[3]



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**(Question 9 continued)**

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

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- (d) Explain this trend in the atomic radii of the atoms in the ethanol molecule [3]



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10. Sulfur dioxide,  $\text{SO}_2$ , 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  $\text{SO}_2$ . [1]

(iii) Deduce the electron domain geometry and molecular geometry of  $\text{SO}_2$ . [2]

Electron domain geometry: .....  
.....  
Molecular domain geometry: .....  
.....

(iv) Explain the polarity of the  $\text{SO}_2$  molecule. [2]

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(This question continues on the following page)



**(Question 10 continued)**

(b) Sulfur dioxide reacts with rain water and oxygen to form sulfuric acid,  $\text{H}_2\text{SO}_4$ .

State an equation for this reaction including the state symbols.

[2]

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