

NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

Paper 2 Structured Questions

9729/02

16 September 2025

2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	/16
2	/14
3	/17
4	/16
5	/12
Paper 2 Total	/75

	Marks	Weightings
Paper 1	/30	15%
Paper 2	/75	30%
Paper 3	/80	35%
Paper 4	/55	20%

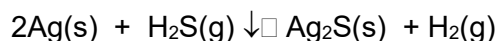
Overall Percentage	
Grade	

This document consists of **19** printed pages.

[Turn over

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

- 1 925 silver, also known as sterling silver, is an alloy that is commonly used to make jewellery. It consists of 92.5% silver and 7.5% other metals, such as copper, by mass. Over time, the alloy can form a tarnish of $\text{Ag}_2\text{S}(\text{s})$ when it reacts with hydrogen sulfide, as represented by the following equation.



- (a) (i) Write the full electronic configuration for copper.

..... [1]

- (ii) State and explain the difference in atomic radii for silver and copper.

.....

 [2]

- (b) The Ag_2S tarnish on sterling silver can be removed until only sterling silver remains. A student weighs a tarnished sterling silver sample both before and after removing the Ag_2S and records the data in Table 1.1.

Table 1.1

mass before tarnish removal /g	54.23
mass after tarnish removal /g	52.34

Assuming that only $\text{Ag}_2\text{S}(\text{s})$ is removed, calculate the amount of silver atoms removed.

[1]

- (c) (i) Suggest and explain the relative magnitudes of the lattice energy of the silver compounds, Ag_2S , Ag_2O and Ag_2Se .

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[2]

- (ii) Using relevant data from the *Data Booklet* and Table 1.2, construct an energy level diagram to calculate the lattice energy of Ag_2O .

Table 1.2

standard enthalpy change of atomisation of silver	+285 kJ mol ⁻¹
1 st electron affinity of oxygen	-141 kJ mol ⁻¹
2 nd electron affinity of oxygen	+798 kJ mol ⁻¹
standard enthalpy change of formation of $\text{Ag}_2\text{O}(\text{s})$	-31 kJ mol ⁻¹

- (d) Rhodium plating is a process used to protect sterling silver from tarnishing. This involves electroplating (depositing) solid rhodium, $\text{Rh}(\text{s})$, onto the surface of the metal from an acidified solution of $\text{Rh}_2(\text{SO}_4)_3(\text{aq})$. Oxygen gas is produced during this process.

[4]

One of the half equations involved in this reaction is



- (i) Write the half equation for the formation of oxygen gas in this reaction and hence, write the balanced ionic equation for the overall reaction.

.....
 [2]

- (ii) Calculate the value of E^\ominus_{cell} for the overall reaction in (i).

[1]

- (iii) Based on your answer to (ii), explain why this process requires the use of an external power source.

.....

 [1]

- (iv) Calculate the current that must be supplied for 3.5 g of Rh to be plated onto a piece of sterling silver in 3 minutes.

[2]

[Total : 16]

- 2 (a) Xenon is a noble gas and forms various fluorides with fluorine. Two of these are xenon difluoride, XeF_2 , and xenon tetrafluoride, XeF_4 , which are crystalline solids with melting points of 140°C and 112°C respectively.

- (i) Draw the dot-and-cross diagrams for XeF_2 and XeF_4 and hence state their molecular shapes.

[3]

- (ii) Even though XeF_4 has more electrons and is hence expected to have greater intermolecular forces than XeF_2 , its melting point is lower. Suggest why XeF_2 has a higher melting point than XeF_4 .

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[1]

- (iii) Using your knowledge of covalent bond formation, explain why

- xenon reacts with fluorine but neon does not.

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- xenon reacts with fluorine but not with iodine.

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[2]

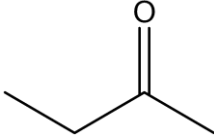
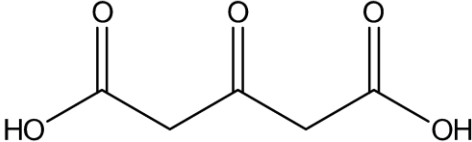
- (b) **P** and **Q** are compounds containing the same functional groups.

Both compounds

- readily decolourise bromine in the dark

- liberate a gas with sodium metal
- do not have O atom bonded to an unsaturated carbon atom
- react with hot acidified potassium manganate(VII) to give the products as shown in Table 2.1.

Table 2.1

compound	products of oxidation
P ($\text{C}_6\text{H}_{12}\text{O}$)	 and CO_2
Q ($\text{C}_5\text{H}_8\text{O}$)	

- (i) Considering the molecular formulae of the two compounds together with the information given above, name the two functional groups that are present in compounds **P** and **Q**.

[2]

- (ii) Suggest the structures of compounds **P** and **Q**.

Compound P	Compound Q

[2]

- (c) Compound **R**, $\text{C}_9\text{H}_{18}\text{O}_2$, has the same two functional groups as **P** and **Q** in (b). Upon strong oxidation by hot acidified KMnO_4 , compound **S**, $\text{C}_6\text{H}_{12}\text{O}_2$, and compound **T**, $\text{C}_3\text{H}_4\text{O}_3$, are obtained.

The following four reagents were used to test compounds **S** and **T**, and the results are shown in the table below.

test reagent	result of test with	
	compound S	compound T
Na(s)	fizzes	fizzes
NaHCO ₃ (aq)	no reaction	fizzes
I ₂ (aq) + OH ⁻ (aq), warm	no reaction	yellow ppt
2,4-DNPH	orange ppt	orange ppt

- (i) By considering the test results with Na(s) and NaHCO₃(aq), name the functional group that is present in **S** and **T**.

Functional group present in **S**:

Functional group present in **T**:

[2]

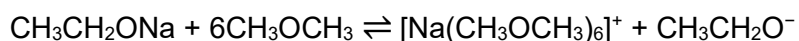
- (ii) Suggest the structures of compounds **S** and **T**.

Compound S	Compound T

[2]

[Total : 14]

- 3 (a) A sodium ethoxide slurry is prepared by dissolving sodium in dry ethanol. When this slurry is transferred into liquid dimethyl ether, CH_3OCH_3 , at 40°C , the following equilibrium is established.



- (i) Write a balanced equation for the reaction of ethanol with sodium.

..... [1]

- (ii) Using your knowledge of VSEPR theory, state and explain the bond angle around the oxygen atom in CH_3OCH_3 .

.....

 [2]

- (b) The strongly basic ethoxide ion, $\text{CH}_3\text{CH}_2\text{O}^-$, removes a proton from compound **A**, giving the anion shown in Fig. 3.1.

Intramolecular attack of the anion on the $\text{C}-\text{Cl}$ bond forms compound **B**.

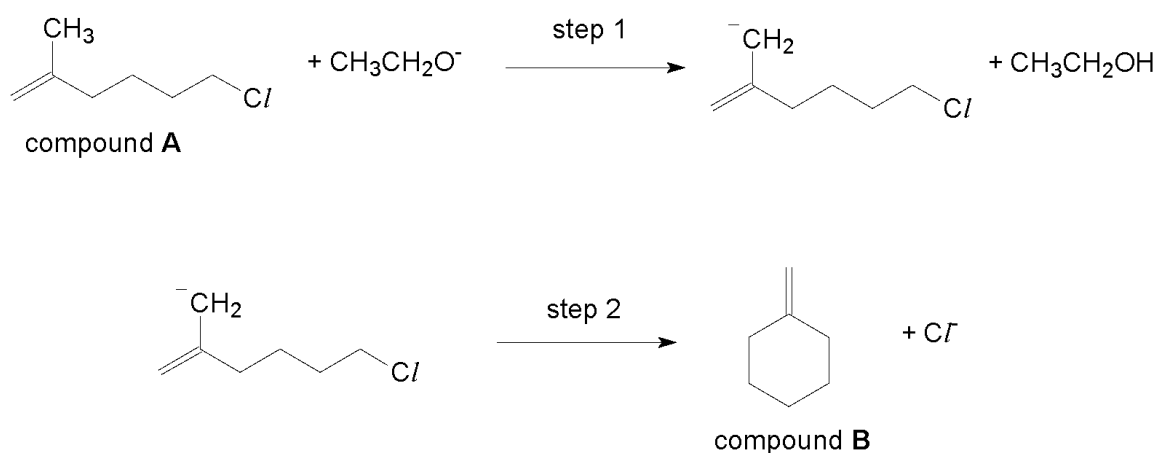


Fig. 3.1

Show the mechanism for step 2 on Fig. 3.1 by adding a lone pair, curly arrows and dipoles.

State the name of the mechanism involved.

..... [2]

- (c) Finely powdered sodium ethoxide burns in excess oxygen to give sodium carbonate, carbon dioxide and water as the only products.

Balance the chemical equation for this combustion.



[1]

- (d) Given the $\text{p}K_{\text{a}}$ values, explain the order of acidity of the following compounds in aqueous medium.

compound	$\text{p}K_{\text{a}}$
ethanol	15.9
phenol	10.0
ethanoic acid	4.76

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[3]

- (e) 2-bromobutane can be used to synthesise propanoic acid by the three-step route shown in Fig. 3.2.

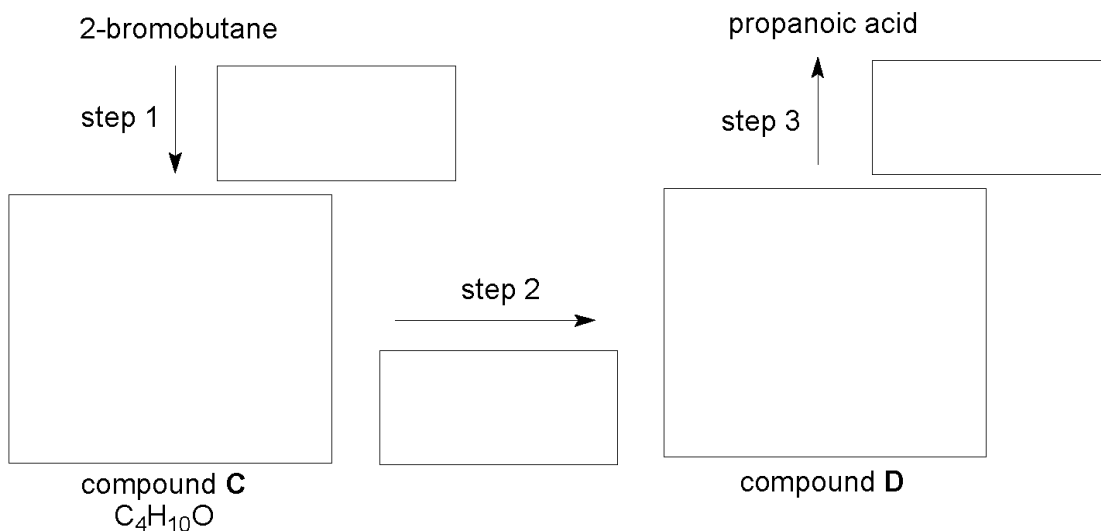


Fig. 3.2

State the reagents and conditions required for each step and suggest structures for the organic compounds, **C** and **D**.

[5]

- (f) The K_b of a secondary amine, $R_1(R_2)NH$, is $5.75 \times 10^{-4} \text{ mol dm}^{-3}$. A 1.50 g sample of the amine is dissolved in water and the solution is made up to 1.00 dm^3 . The pH of the resulting solution is 11.55.

Calculate the relative molecular mass of $R_1(R_2)NH$, and suggest a structural formula for $R_1(R_2)NH$. Show your working clearly.

[3]

[Total : 17]

- 4 Although carbon monoxide, CO, is a poisonous gas, it is an important starting material in the synthesis of many industrially important compounds.

(a) (i) Draw a dot-and-cross diagram to show the bonding in carbon monoxide.

[1]

(ii) Suggest why carbon monoxide is poisonous.

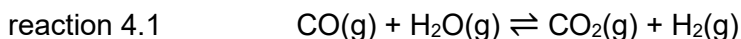
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[1]

Carbon monoxide can undergo water–gas shift reaction. The carbon monoxide gas reacts with steam to produce carbon dioxide gas and hydrogen gas.



(b) Explain the difference in boiling points of CO and of CO₂ in terms of the type and relative strength of the intermolecular forces.

species	boiling point/ °C
CO	–191
CO ₂	–78

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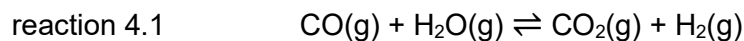
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[2]

- (c) 0.200 mol of carbon monoxide and 0.200 mol of steam was placed in reaction vessel and allowed to react at a temperature of 800 K. The percentage of carbon monoxide reacted was found to be 77.5%.



- (i) Write the expression for the equilibrium constant, K_c , for reaction 4.1.

[1]

- (ii) Calculate the value of the equilibrium constant, K_c , at 800 K.

[2]

- (iii) The Gibbs free energy change of reaction, ΔG_r , for reaction 4.1 is $-18.4 \text{ kJ mol}^{-1}$ at 600 K. The relationship between the equilibrium constant and the Gibbs free energy change of this reaction can be expressed as:

$$\Delta G = -RT \ln K_c$$

Calculate the value of K_c for the reaction 4.1 at 600 K.

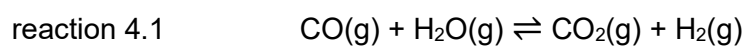
[1]

(d) Table 4.1 gives data relevant to this question.

Table 4.1

$\otimes H_f^\ominus \text{CO(g)}$	$-110.5 \text{ kJ mol}^{-1}$
$\otimes H_f^\ominus \text{CO}_2\text{(g)}$	$-393.5 \text{ kJ mol}^{-1}$
$\otimes H_f^\ominus \text{H}_2\text{O(g)}$	$-241.1 \text{ kJ mol}^{-1}$

Using the data given in Table 4.1, construct an energy cycle to calculate the enthalpy change of reaction for reaction 4.1.



[2]

- (e) William Henry studied the equilibria when an ideal gas dissolves in a liquid. He proposed that the concentration of the gas dissolved in a liquid is proportional to the partial pressure of the gas above the liquid surface. This proportionality factor is called Henry's law constant, K_H .

The Henry's law constant, K_H , can be represented as the equation below.

$$K_H = \frac{\text{maximum concentration of gas dissolved in mol dm}^3}{\text{partial pressure of gas in atm}}$$

Sealed containers of fizzy drinks contain dissolved CO_2 . This dissolved CO_2 is in equilibrium with a very small quantity of gaseous CO_2 at the top of the container.



The Henry's law constant for CO_2 is $3.3 \times 10^{-2} \text{ mol dm}^{-3} \text{ atm}^{-1}$ at 25°C .

- (i) The partial pressure of CO_2 gas in a can of 250 cm^3 fizzy drink is 3.0 atm at 25°C .

Calculate the concentration of CO_2 in the fizzy drink and hence the mass of CO_2 dissolved in the 250 cm^3 of fizzy drink.

[2]

Fig. 4.1 shows the relationship between Henry's law constant and temperature.

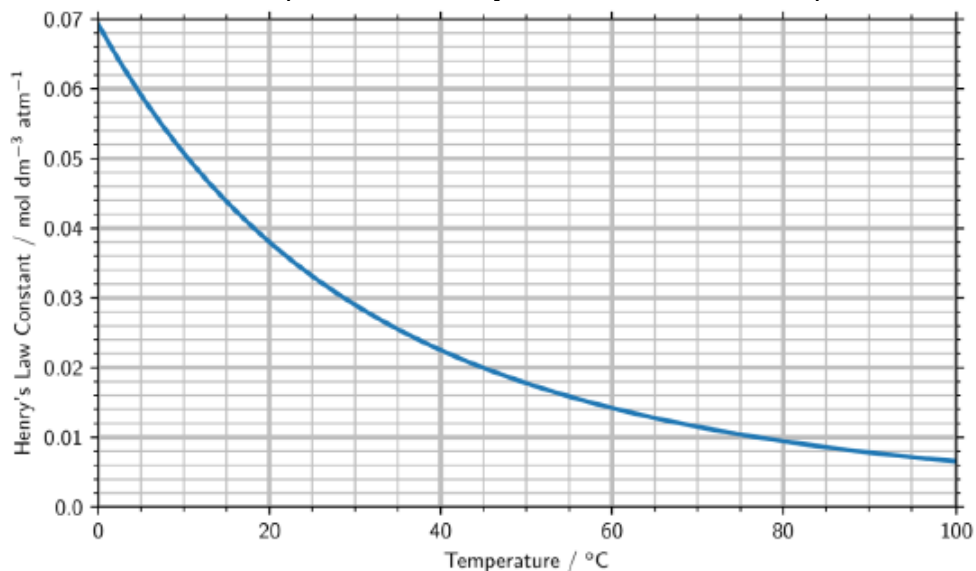


Fig. 4.1

- (ii) The maximum pressure that a fizzy canned drink can withstand is 6.2 atm. Using the concentration of CO₂ in the fizzy drink calculated in (i), calculate the value of K_H at this pressure.

[1]

- (iii) Using Fig. 4.1, determine the maximum temperature at which the fizzy canned drink can be stored safely.

Maximum temperature:

[1]

- (iv) Deduce, with reasoning, the sign of enthalpy change for reaction 4.2.

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[2]

[Total : 16]

- 5 Plastic takeaway containers for food are commonly made of polypropene (PP) which is microwave safe and chemically inert.

Polymerisation is a chemical process where small molecules (monomers) combine to form a large molecule (polymer) through the formation of covalent bonds. Fig 5.1 shows the process of joining many propene monomers to form polypropene. The type of polymerisation is known as addition polymerisation as only 1 single product is formed.

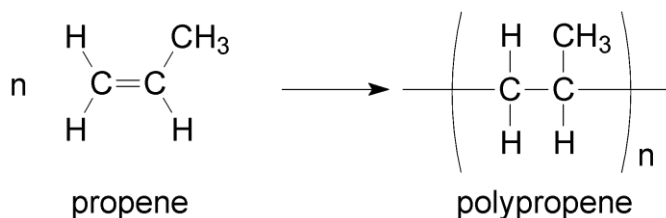


Fig 5.1

- (a) (i) The polymerisation of 1 mole of propene to form polypropene (Fig 5.1) has a standard entropy change of $-110 \text{ J mol}^{-1} \text{ K}^{-1}$.

Account for the negative sign of the standard entropy change for polymerisation.

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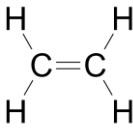
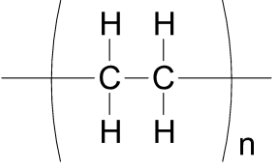
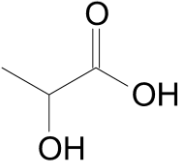
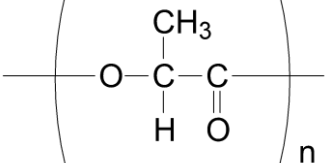
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[2]

- (ii) Given that the standard enthalpy change of polymerisation of polypropene is $-55.0 \text{ kJ mol}^{-1}$, calculate the maximum temperature for the reaction to be spontaneous.

[2]

The increasing environmental concerns over plastic pollution have led to innovations in food packaging design. Many food establishments now use paper-based takeaway containers coated with either polyethene (PE) or polylactic acid (PLA) instead of conventional plastic containers.

monomer	polymer
 <p>ethene</p>	 <p>polyethene (PE)</p>
 <p>lactic acid</p>	 <p>polylactic acid (PLA)</p>

- (b) (i) State the IUPAC name of lactic acid.

..... [1]

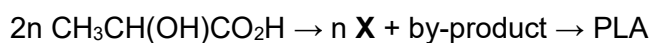
- (ii) Similar to propene, ethene undergoes addition polymerisation to form polyethene. Lactic acid undergoes a different type of polymerisation as a by-product is formed. Identify the by-product and hence state the type of polymerisation undergone by lactic acid to form PLA.

By-product:

Type of polymerisation:

[1]

- (iii) The equation for polymerisation of lactic acid to form PLA is found to be:



X is a cyclic intermediate with the molecular formula of $\text{C}_6\text{H}_8\text{O}_4$.

X does not react with Na.

Draw the skeletal structure of **X**.

[1]

- (c) Tom Yum soup is cooked with Thai bird's eye chillies, lime juice and lemongrass to give the characteristic sour and spicy flavour. A Thai food stall vendor is choosing between takeaway food containers coated with PE or PLA to contain hot Tom Yum soup.

By considering the structures of PE and PLA, and the properties of Tom Yum soup, explain which type of takeaway food container you would recommend to the Thai food stall vendor.

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[2]

- (d) Microplastics are particles with sizes ranging from 1 μm to 5 mm in any dimension (1 mm = 1000 μm).

While PE-coated and PLA-coated paper containers still contain plastic elements, they use significantly less plastic than traditional PP containers, thereby reducing the potential for microplastic generation.

A researcher studied the degradation of samples of PE and PLA in an aqueous condition with a similar salt concentration as seawater and with exposure to UV light after 2 years. He then determined the proportion of particles with various sizes of $\leq 3 \mu\text{m}$, as shown in Fig 5.2.

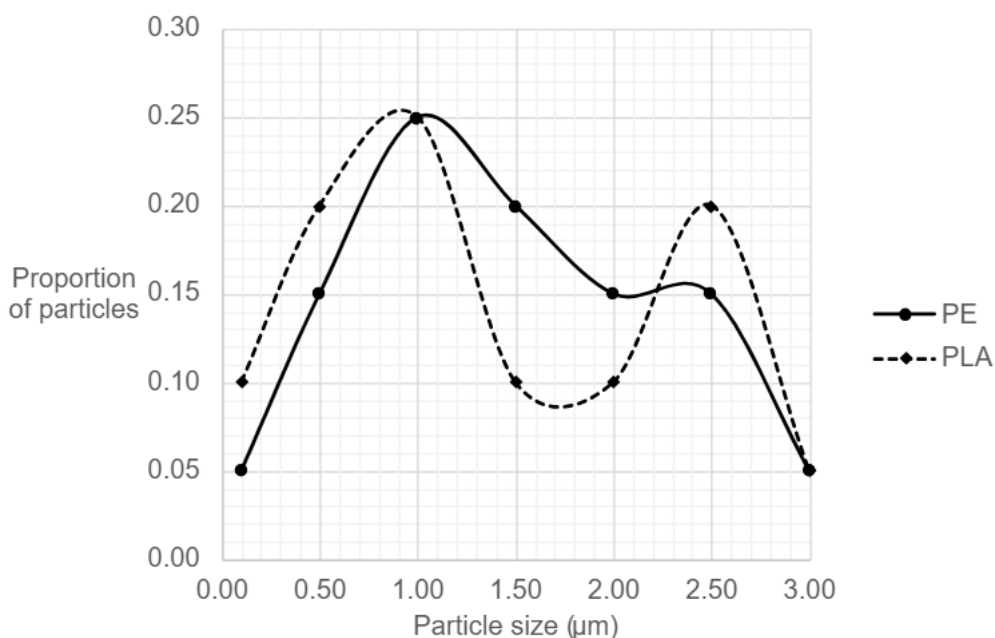


Fig 5.2

- (i) With reference to Fig 5.2, explain whether you would expect PE or PLA to degrade and generate more microplastics in the sea.

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[2]

- (ii) State one other condition for the degradation of PE and PLA in the sea that the researcher should have considered in his investigation.

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[1]

[Total: 12]