

Polymers

Mark Scheme



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1. Polymers are very large molecules formed when many small, identical molecules, called monomers, join together to create long, repeating chains.

- a. The diagram below illustrates the addition polymer formed from ethene.

Which terms describe this polymer?

A – is the only correct answer.	1 mark
	Total: 1 mark

- b. A student is categorising polymers.

Which row correctly identifies the origin of each polymer?

A – is the only correct answer.	1 mark
	Total: 1 mark

- c. The structure below represents a section of a polymer chain.

Which of the substances below undergoes polymerisation to produce this structure?

D – is the only correct answer.	1 mark
	Total: 1 mark

- d. Which functional group does a monomer need to contain to form addition polymers?

A – is the only correct answer.	1 mark
	Total: 1 mark

- e. Bromine reacts with ethene to form a saturated compound.

Draw the full displayed formula of the product formed in this reaction.

C – is the only correct answer.	1 mark
	Total: 1 mark

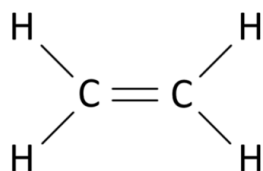
- f. Glycine is an amino acid used by the body to make proteins.

Identify the **two** functional groups found in a molecule of glycine from the table below.

D – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. The figure below shows the displayed formula of the monomer ethene.



- a. What feature of ethene molecules allows them to act as monomers?

They contain a carbon to carbon <u>double bond</u> .	1 mark
Allow unsaturation / unsaturated. Allow C=C	
	Total: 1 mark

- b. Ethene is an alkene.

What is the general formula for an alkene?

C_nH_{2n}	1 mark
	Total: 1 mark

- c. Ethene undergoes addition polymerisation to form poly(ethene).

Draw the **displayed formulae**, for poly(ethene).

Award 1 mark for the single bonds between carbons and all H atoms correct.	1 mark
Award 1 mark for the extension bonds passing through brackets and 'n' at bottom right.	1 mark
	Total: 1 mark

- d. Polymers can be made from different monomers. What are the monomers in DNA called?

Nucleotide(s).	1 mark
	Total: 1 mark

- e. As mentioned DNA is made up of monomers.

What are the **three** main chemical parts of a DNA monomer?

Sugar / deoxyribose.	
Phosphate	
Base or nitrogenous base.	
Any two correct = 1 mark All three correct = 2 marks	
	Total: 2 marks

- f. Describe how dichloroethene monomers can form a polymer.

A description to include the following:	
monomers / molecules join / link (together)	1 mark
(and the) double bond opens / breaks	1 mark
	Total: 2 marks

- g. Calculate the relative formula mass of a poly(chloroethene) molecule made from 4150 chloroethene molecules, C_2H_3Cl .

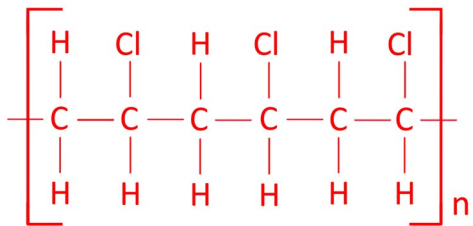
Give your answer to **three significant figures**. Show your working.

Mr of chloroethene = 62.5	1 mark
Total mass = $62.5 \times 4150 = 259,375$	
Answer to 3 sig figs = 259 000	1 mark
	Total: 2 marks

(Total for Question 2 is 11 marks)

3. Poly(chloroethene) is a polymer made from chloroethene.
A molecule of chloroethene is shown in the figure below.

- a. Draw a section of a poly(chloroethene) molecule containing **three** repeating units, showing all bonds.

	
Award 1 mark for the chain of 6 carbon atoms connected by single bonds.	1 mark
Award 1 mark for the correct number of chlorine atoms shown.	1 mark
Award 1 mark for the extension bonds passing through brackets and 'n' at bottom right.	1 mark
	Total: 3 marks

- b. What form of polymer is poly(chloroethene)?

Addition polymer	1 mark
	Total: 1 mark

- c. A molecule of poly(chloroethene) has a relative formula mass (Mr) of 187,500.

Calculate the number of chloroethene monomers (C_2H_3Cl) joined together to form this molecule.

(Relative atomic masses: H = 1.00 , C = 12.0 , Cl = 35.5)

Show your working.

Mr of monomer (C_2H_3Cl) = 62.5	1 mark
$187,500 \div 62.5 = 3000$	1 mark
	Total: 2 marks

Poly(chloroethene), also known as PVC, is a polymer used extensively for window frames, water pipes, and electrical insulation.

Like poly(ethene), it is manufactured using raw materials obtained from crude oil.

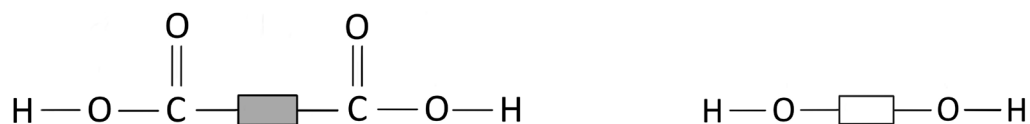
- d. Explain the environmental and safety problems associated with the manufacture and disposal of poly(chloroethene).

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about environmental problems (e.g., "it pollutes", "bad for the environment") without linking to the specific chemistry of PVC.
Level 2	3 - 4	An explanation is provided that covers manufacture and disposal but may lack specific scientific detail (e.g., naming specific gases) or logic.
Level 3	5 - 6	A detailed and coherent explanation is provided that covers both manufacture and disposal. The student identifies specific environmental impacts (e.g., non-renewable resources, specific toxic gases).

Indicative content:	
Manufacture: - Derived from crude oil (finite / non-renewable resource) - Fractional distillation / cracking / polymerisation requires energy. - Energy often comes from burning fossil fuels → CO₂ (global warming). - Production of chlorine involves electrolysis (high energy use). - Intermediates can be toxic / hazardous. Disposal: - Landfill: polymers are non-biodegradable. - Take up valuable space / stay in ground for hundreds of years. - Wastes the raw material. Incineration: - Burning releases carbon dioxide (CO₂) → global warming. - Burning PVC releases hydrogen chloride (HCl) is acidic / causes acid rain / is toxic. Recycling: Difficult to sort PVC from other plastics	
	Total: 6 marks

(Total for Question 3 is 12 marks)

4. Esters can be made from the two different molecules shown in the figure below.



- a. Complete the diagram to show a section of the ester made from these two molecules. Include all of the atoms and all of the bonds in the ester molecule.

$\text{H}-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-\boxed{}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\boxed{}-\text{O}-\text{H}$	
Accept any correct version of this diagram.	
Award 1 mark for the ester link correct. That's the carbon double bonded to oxygen while at the same time that same carbon is also bonded to the other oxygen.	1 mark
Award 1 mark for the rest of the repeating unit correct including continuation bonds at both ends.	1 mark
Total: 2 marks	

- b. Identify the type of polymerisation that takes place when this polymer forms.

Condensation (polymerisation)	1 mark
Because a small molecule has been lost.	
Allow water is lost or formed. Allow HCl is formed.	
Total: 2 marks	

- c. Synthetic polymers are disposed of in landfill sites and by burning.

- i. Describe **two** problems caused by the disposal of synthetic polymers in landfill sites.

A description to include any two from:	
- Fills up landfill sites / limited space. - Not biodegradable / does not break down. - Visual pollution / litter.	
Total: 2 marks	

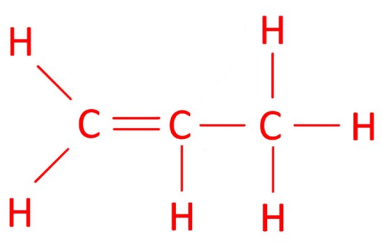
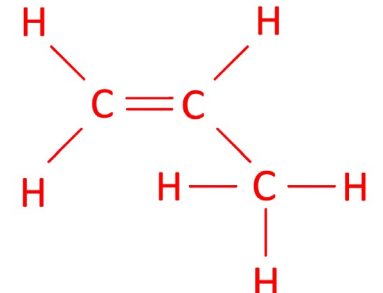
- ii. Describe one problem caused by burning synthetic polymers.

A description to include any one from:	
- They release carbon dioxide / CO₂ / greenhouse gases. - Releases toxic gases / acidic gases.	1 mark
Total: 1 mark	

The structural formulae of two synthetic polymers are given below.

Polymer X	$\begin{array}{ccccccccccc} & -\text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & \text{CH}_2- & - \\ & & & & & & & & & & \\ & & \text{CH}_3 & & \text{CH}_3 & & \text{CH}_3 & & \text{CH}_3 & & \end{array}$
Polymer Y	$\begin{array}{ccccccccccc} & & \text{O} & & \text{O} & & \text{O} & & \text{O} & & \\ & & & & & & & & & & \\ -\text{O}- & \text{C}- & \text{[]} & -\text{C}- & \text{O}- & \text{[]} & -\text{O}- & \text{C}- & \text{[]} & -\text{C}- & \text{O}- & \text{[]} & -\text{O}- \\ & & & & & & & & & & \end{array}$

- d. Draw the structural formula of the **monomer** of polymer X.

		
Accept any correct version of the diagram above.		2 marks
		Total: 2 marks

- e. Deduce the **two** types of organic compound which have reacted to form polymer Y.

Carboxylic acid.	1 mark
Allow dicarboxylic acid.	
Alcohol.	1 mark
	Total: 2 marks

- f. Explain the difference between addition and condensation polymers.

In your explanation you should identify which type of polymer, addition or condensation X and Y are.

An explanation to include the following:	
Difference:	
• Addition (polymerisation) involves no loss of small molecules / atoms.	1 mark
• Condensation (polymerisation) involves loss of a small molecule / water.	1 mark
Identification:	
• Polymer X is Addition.	1 mark
• Polymer Y is Condensation.	1 mark
	Total: 3 marks

(Total for Question 4 is 13 marks)

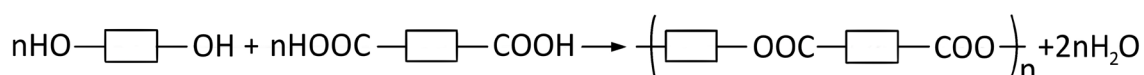
5. Ethene is used to produce poly(ethene).

a. Draw the bonds to complete the displayed formulae of ethene and poly(ethene) in the equation.

$n \begin{array}{cc} \text{H} & \text{H} \\ & \\ \text{C} & = \text{C} \\ & \\ \text{H} & \text{H} \end{array} \longrightarrow \left(\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{H} & \text{H} \end{array} \right)_n$	
Left hand side (monomer): Double bond drawn between carbon atoms (C=C) AND single bonds to all four hydrogen atoms	1 mark
Right hand side (polymer): Single bond drawn between carbon atoms (C–C) AND single bonds to all four hydrogen atoms AND continuation bonds (trailing bonds) extending through/touching the brackets.	1 mark
	Total: 2 marks

A different type of polymerisation reaction is required to manufacture polyesters.

This process is represented by the following general equation:



b. Poly(ethene) is an addition polymer, whereas polyester is a condensation polymer.

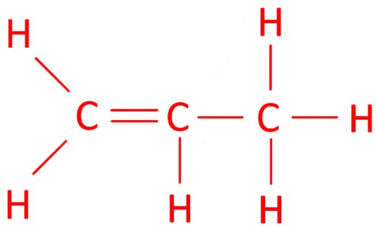
Explain the differences between these two methods of polymerisation.

An explanation to include any four comparative points	
Monomer type: addition uses alkenes / monomers with C=C bonds whereas condensation uses monomers with two different functional groups (e.g. alcohol and carboxylic acid). Number of monomers: addition usually involves one type of monomer whereas condensation usually involves two different types of monomer. Products formed: addition produces only the polymer (one product) whereas condensation produces the polymer plus a small molecule / water. Reaction mechanism: addition involves the opening of the carbon-carbon double bond whereas condensation involves the reaction between functional groups to form a linkage (ester/amide). Addition polymer has a backbone of carbon atoms only whereas condensation polymer backbone contains other atoms (e.g. oxygen / nitrogen) in the chain.	
	Total: 4 marks

(Total for Question 5 is 6 marks)

6. Propene is an alkene. The formula of its molecule is C₃H₆.

a. Draw the structure of a **propene molecule**, showing **all** of the bonds.

	
Accept any correct versions of the figure above.	
Award 1 mark for the correct structure.	1 mark
Award 1 mark for the correct bonds.	1 mark
	Total: 2 marks

b. Propane is a saturated hydrocarbon, whereas propene is unsaturated.

Describe a chemical test to distinguish between a sample of propane and a sample of propene.
Include the expected colour change for the propene.

A description of the bromine test:	
Add <u>bromine water</u> to the sample or vice versa.	1 mark
Propene: turns from orange to <u>colourless</u> .	1 mark
Propane: remains orange / brown / no colour change.	1 mark
	Total: 3 marks

c. Calculate the percentage by mass of carbon in a propene molecule (C₃H₆).

(Relative atomic masses: H = 1.00 , C = 12.0). Give your answer to **three** significant figures.

Mr of propene = (3 × 12) + (6 × 1) = 42	1 mark
(36 ÷ 42) × 100	1 mark
= 85.7 %	1 mark
	Total: 3 marks

d. Poly(propene) is a widely used plastic manufactured from the monomer propene.

Describe the chemical reaction that turns propene into poly(propene).

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made about plastic, uses, or the reaction. The chemistry may be vague (e.g., "particles join together"). There is no clear link between properties and uses.
Level 2	3 - 4	The reaction is described with some correct chemical details (e.g., mentioning double bonds or addition). Some properties or uses are given, but the link between property and use may be weak or missing. The answer has some structure but may lack precision.
Level 3	5 - 6	The method of polymerisation is described clearly, including specific reference to the behaviour of the double bond. At least one use is linked to a specific, relevant property.

Indicative content:	
The chemical reaction: • Polypropene is formed by addition polymerisation. • Many small molecules (monomers) join together... • ...to form a very long chain / large molecule (polymer). • The monomer is propene (an alkene). • The reaction involves the double bond (C=C) in the propene monomer... • ...opening up / breaking to form single bonds (connecting to adjacent carbons). • Equation: $n(\text{C}_3\text{H}_6) \rightarrow -(\text{C}_3\text{H}_6)_n-$ (or described in words). • Requires a catalyst / high pressure / heat (allow general references to reaction conditions). Properties linked to uses: • Property: Strong / Tough / Durable. • Use: Ropes, crates, carpets, garden furniture. • Property: Waterproof / Unreactive / Non-toxic. • Use: Food containers, water pipes, medical equipment. • Property: Flexible / Can be moulded. • Use: Plastic bags, bottles, packaging, electrical insulation. • Property: High melting point (relative to other common plastics). • Use: Containers for hot food / dishwasher safe containers.	
	Total: 6 marks

(Total for Question 6 is 14 marks)