

1(a). Metal extraction produces a lot of waste. The zinc ions from this waste could leak into watercourses and contaminate soil. This plant, Alpine Penny-cress, grows on waste heaps that contain toxic zinc ions.

The cress plants take up the zinc ions and store them in their leaves.



Explain how the planting of Alpine Penny-cress could be used to recycle zinc.

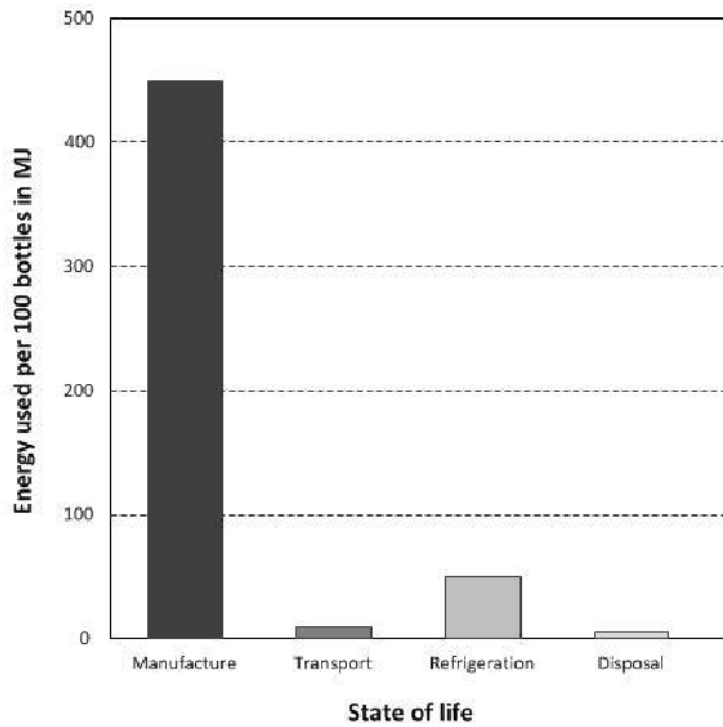
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----- [1]

(b). Explain how growing these plants could reduce risk.

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----- [2]

2. Disposable drink bottles are made from a polymer called PET.

This chart shows the energy used in millions of joules (MJ) for 100 PET bottles during their lifetime.



Jay talks about recycling waste bottles.



**Jay**

'I save my empty bottles and take them to a recycling point. This saves on the energy used in disposal of the bottles.'

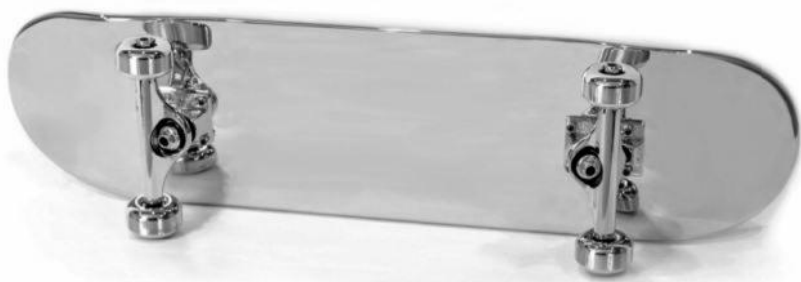
Does saving energy during disposal make a large impact on the life cycle assessment for 100 bottles?

Use data from the chart to explain your answer.

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[2]

3(a). Sam works for a company that makes skateboards.



Customers complain that their skateboards lose performance once they have got wet.

Skateboards have bearings in each wheel to help the wheels rotate smoothly and freely.



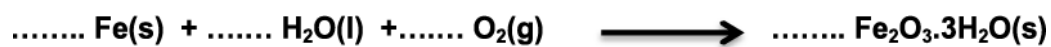
**Skateboard wheel bearing**

The bearings in the wheels contain smaller steel ball bearings. These rust if they get wet.

The word equation for rusting is:

**iron + water + oxygen  $\longrightarrow$  rust (hydrated iron(III) oxide)**

Balance the symbol equation for the formation of rust.



[2]

(b). Sam notices that this skateboard does not perform as well.

Suggest, with explanation, a reason for this and how the problem could be solved.

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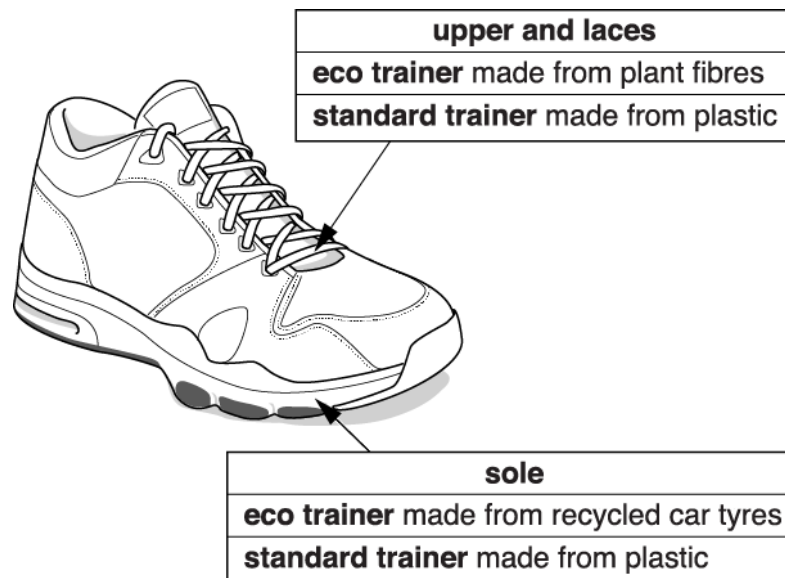
[2]

4. A company makes a **standard** trainer using plastics made from crude oil.

They make a new **eco trainer** from plant fibres and recycled car tyres.

They expect a Life Cycle Assessment (LCA) to show that the eco trainers do less harm to the environment than standard trainers.

Here is data on the LCA of each trainer.



	Eco trainers		Standard trainers	
	Energy (MJ)	Greenhouse gases made (kg CO <sub>2</sub> )	Energy (MJ)	Greenhouse gases made (kg CO <sub>2</sub> )
Making materials for the trainers	1.6	0.1	6.0	4.2
Making the trainers from the materials	1.4	1.0	4.2	3.7
Disposing of the trainers	0.8	0.6	0.8	0.6

Suggest reasons why the company expected the LCA would show eco trainers do less harm to the environment than standard trainers. Does the data show the company was right? What additional information is needed to complete the LCA?



*The quality of written communication will be assessed in your answer.*

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[6]

5(a). Scientists compare the environmental impact of three types of disposable grocery bag.

They do this by carrying out a Life Cycle Assessment (LCA) for each type of bag.

They compare bags made of paper, biodegradable plastic and polythene.

The results for each whole LCA are shown in the table.

	Totals for 1000 bags for the whole LCA		
	paper (30% recycled fibre)	biodegradable plastic	polythene
Energy use (MJ)	2620	2070	763
Fossil fuel use (kg)	23.2	41.5	14.9
Municipal solid waste (kg)	33.9	19.2	7.0
Greenhouse gas emissions (kg CO <sub>2</sub> )	80	180	40
Fresh water use (litres)	4520	4580	260

Which of the following factors should **not** be included in a comparison of the environmental impact of these three types of disposable grocery bag?

Put ticks (✓) in the boxes next to the **two** statements that should not be included.

The energy input for making the bags from the fibres or polymers.

The environmental impact of disposing of the bags.

Whether customers are charged for bags.

The environmental impact of making the fibres or polymers from raw materials.

Which bags customers prefer to use.

The energy input as the bags are being disposed.

[2]

(b).

(i) A government decides to ban the use of disposable bags made from polythene.

Explain why this data may persuade the government to change this decision.

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(ii) There are reasons other than the data from Life Cycle Assessments that might influence the government's decision to ban disposable bags made from polythene.

Suggest and explain **two** of these reasons.

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----- [2]



6(a). The table shows data from a Life Cycle Assessment for a polyester shirt and for a cotton shirt.

	Fibre production		Fabric weaving		Use (100 washes)		Disposal by burning (incineration)	
	Polyester	Cotton	Polyester	Cotton	Polyester	Cotton	Polyester	Cotton
<b>Energy (MJ)</b>	97	60	33	40	340	340	-33	-7
<b>Oil or gas (kg)</b>	1.5	-	-	-	-	-	-	-
<b>Fertilisers (kg)</b>	-	457	-	-	-	-	-	-
<b>Pesticides (g)</b>	-	16	-	-	-	-	-	-
<b>Water (dm<sup>3</sup>)</b>	17	22 200	1290	3900	4900	4900	-	-
<b>Carbon dioxide emissions (kg)</b>	2.3	3.0	1.5	2.3	-	-	5.8	5.5

The table shows **positive** figures for energy during making and using the shirts.

The table shows **negative** figures for energy during disposal of the shirts.

Suggest reasons for this difference.

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[2]

(b). Look at the energy and water data in the table.

Use these data to compare the sustainability of shirts made from polyester and from cotton.

Show any working.

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[3]

7.

Manganese is a metallic element.

Manganese is made by heating manganese oxide,  $\text{MnO}_2$ , with carbon.

Carbon monoxide is also formed.

(i) Write a **balanced chemical** equation for this reaction.

Include state symbols in your equation.

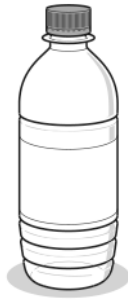
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(ii) Explain why carbon can be used to extract manganese from its compounds.

Use ideas about reactivity and reduction in your answer.

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----- [2]

8(a). Soft drinks are sold in containers made from PET (a plastic), aluminium and glass.



PET bottle



Aluminium can



Glass bottle

All three containers are non-biodegradable.

Table 10.1 and Fig. 10.1 show information about the life cycle assessment of containers from two different companies.

Company 1

	Total life cycle energy and waste per 1000 litres of drink			
	Energy use (GJ)	Emissions	Waste produced	
		CO <sub>2</sub> equivalent emission (kg)	Mass (kg)	Volume (m <sup>3</sup> )
PET bottle	4.1	180	48	0.2
Aluminium can	5.9	440	120	0.3
Glass bottle	9.8	770	730	0.6

Table 10.1

Company 2

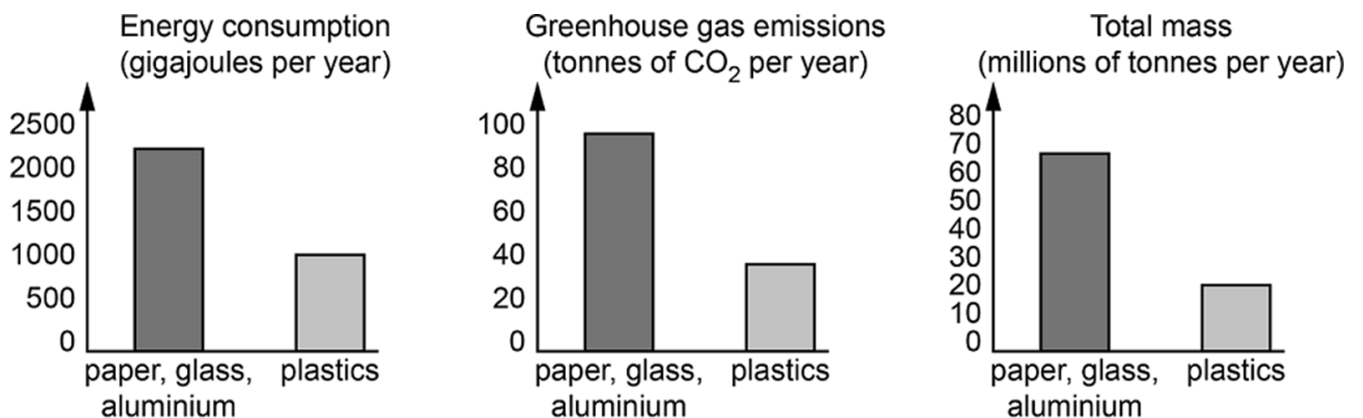


Fig 10.1



(b). The way that plastic bottles are collected for recycling has changed over time.

In the past, people had to sort their waste plastic bottles and take them to bins in towns or supermarket car parks.

Now, over 90% of local authorities collected waste plastic bottles directly from homes.

Suggest how this change affects the life cycle assessment of plastic bottles.

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----- [1]

(c). **Company 1** and **Company 2** both manufacture drinks containers from polymers.

Some people want to ban the use of all non-biodegradable packaging, including polymers.

Explain why these people have different views to the polymer companies about the use of non-biodegradable materials

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----- [1]

**END OF QUESTION PAPER**

### Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
1	a	zinc is recovered at the end of the process / a way of making zinc from waste ✓	1	
	b	zinc ions are toxic if they enter drinking water / water supplies ✓  risk is reduced if zinc ions are stored in plants ✓	2	
		<b>Total</b>	<b>3</b>	
2		(no because) energy of disposal is very small / only about 10 MJ / does not make a big difference ✓  total energy is about 500 MJ / energy cost of manufacture is about 450 MJ ✓	2	
		<b>Total</b>	<b>2</b>	
3	a	$4\text{Fe}(\text{S}) + 6 \text{H}_2\text{O}(\text{l}) + 3\text{O}_2(\text{g}) \Rightarrow 2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}(\text{s})$ ✓✓	2	One mark for 2 or 3 right Two marks for all 4 right  Allow <b><math>2\text{Fe}(\text{s}) + 3\text{H}_2\text{O} + 1 \frac{1}{2} \text{O}_2(\text{g}) \longrightarrow (1)\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}(\text{s})</math></b> ✓
	b	rust is loose so stops the bearings turning the wheels / jams the bearings ✓  one solution from:  coat / galvanise / grease ball bearings to form barrier to keep the water and oxygen from the steel ✓  use another material with the same desirable properties but that does not rust / suggestion of an alternative material such as ceramic ✓	2	
		<b>Total</b>	<b>4</b>	

## Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
4	<p><b>[Level 3]</b> Gives a reason <b>and</b> uses data <b>and</b> details of extra information on the LCA</p> <p>Quality of written communication does not impede communication of the science at this level.</p> <p style="text-align: right;">(5 – 6 marks)</p> <p><b>[Level 2]</b> Gives a reason <b>and</b> uses data <b>or</b> Gives a reason <b>and</b> details of extra information on the LCA <b>or</b> Uses data <b>and</b> details of extra information on the LCA.</p> <p>Quality of written communication partly impedes communication of the science at this level.</p> <p style="text-align: right;">(3 – 4 marks)</p> <p><b>[Level 1]</b> Gives a reason <b>or</b> uses data <b>or</b> details of extra information on the LCA</p> <p>Quality of written communication impedes communication of the science at this level.</p> <p style="text-align: right;">(1 – 2 marks)</p> <p><b>[Level 0]</b> Insufficient or irrelevant science. Answer not worthy of credit.</p> <p style="text-align: right;">(0 marks)</p>	6	<p>This question is targeted at grades up to A/A*</p> <p>Indicative scientific points may include:</p> <p>Reasons why expected to do less harm:</p> <ul style="list-style-type: none"> <li>• Plants are a renewable resource.</li> <li>• Plants are carbon neutral.</li> <li>• Recycled materials don't use resources.</li> <li>• Uses less fossil fuels.</li> <li>• Plastics are manufactured / made from crude oil.</li> </ul> <p>Accept reverse arguments for all points.</p> <p><b>Using Data:</b></p> <ul style="list-style-type: none"> <li>• Calculates or reference to <b>total</b> energy.</li> <li>• Calculates or references to <b>total</b> greenhouse gases.</li> </ul> <p><b>Extra information on LCA</b></p> <ul style="list-style-type: none"> <li>• use of other resources such as water/fertilisers to grow plants</li> <li>• environmental impact of growing crops for making plastic rather than for food crops</li> <li>• how long the trainers last</li> <li>• transportation of the trainers</li> <li>• use of resources, energy or environmental impact of using the trainers</li> </ul> <p><b>Use the L1, L2, L3 annotations in Scoris; do not use ticks.</b></p> <p><b>Examiner's Comments</b></p> <p>There was plenty to write about in this question, but unfortunately, very few reached level 3. Far too much effort went into restating data from the question paper without analysing it or using the prompts in</p>



### Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					<p>the question to structure their answer. Reasons such as plants being carbon neutral were rare, as was the use of the word 'resources.' Some did discuss the total energy and greenhouse gases, but then spoiled their argument by saying the disposal figures were the same. This level was usually given to those giving figures that totalled those in the table. The additional information points were mainly scored by how long they lasted or the impact of their use. A few mentioned water, but no-one discussed the impact of growing crops for materials rather than food.</p>
			<b>Total</b>	<b>6</b>	

### Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a		<p>Whether customers are charged for bags. <input type="checkbox"/></p> <p><input type="checkbox"/></p> <p><input checked="" type="checkbox"/></p> <p><input type="checkbox"/></p> <p>Which bags customers prefer to use. <input checked="" type="checkbox"/></p> <p><input type="checkbox"/></p>	2	
	b	i	<p><i>any two from:</i></p> <p>polythene uses least energy (1)</p> <p>polythene uses least fossil fuel (1)</p> <p>polythene produces least solid waste (1)</p> <p>polythene gives least greenhouse gases (1)</p> <p>polythene uses least water (1)</p>	2	<p><b>allow</b> AW for less eg not so much / lower / low etc instead of least</p> <p>all answers must refer to categories in the table</p> <p><b>ignore</b> reference to cost / biodegradability / strength etc</p>
		ii	<p><i>any two (for or against the ban) from:</i></p> <p>bags may be discarded and litter the environment / they take up space in landfill / harm wildlife (1)</p> <p>polythene will not rot / takes a long time to degrade (1)</p> <p>incineration of polythene bags causes pollution (1)</p> <p>polythene made from crude oil which is finite (1)</p> <p>polythene can be recycled and used to make something else (1)</p> <p>bags could be re-used (1)</p>	2	<p><b>allow</b> other valid ideas</p> <p><b>ignore</b> reference to data from table</p> <p><b>ignore</b> reference to cost / strength / durability</p> <p><b>Examiner's Comments</b></p> <p>The majority of candidates correctly interpreted data from the table to gain both of the marks in (i). Fewer understood the question in (ii), with many still quoting from the table. Only the more able gave additional reasons for or against using disposable bags made of polythene.</p>
			<b>Total</b>	<b>6</b>	

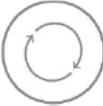
## Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
6	a	during making and using shirts energy is taken in / used (1) during disposal / burning (useful) energy / heat is given out (1)	2	credit 2 marks for “positive is energy used and negative is energy released”  <b>Examiner's Comments</b>  Very few candidates could interpret the negative and positive energy values correctly. Some gained a mark for the idea that making and using the shirts uses energy. Many incorrectly thought that the negative values meant that less energy was being used.

### Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	<p>energy totals are polyester (<math>97 + 33 + 340 - 33 =</math>) 437 (MJ) cotton (<math>60 + 40 + 340 - 7 =</math>) 433 (MJ) (1)</p> <p>water use totals are polyester (<math>17 + 1260 + 4900 =</math>) 6207 (dm<sup>3</sup>) cotton (<math>22200 + 3900 + 4900 =</math>) 31000 (dm<sup>3</sup>) (1)</p> <p>cotton is more sustainable because it uses less energy / polyester is more sustainable because it uses less water (1)</p>	3	<p>give mark for both correct values without working or units</p> <p>values must be linked to correct materials</p> <p><b>do not credit</b> polyester 470 MJ cotton 440 MJ</p> <p>mark third marking point independently of the first two <b>allow</b> ecf from calculations <b>ignore</b> reference to other data</p> <p><b>Examiner's Comments</b></p> <p>Only the stronger candidates could work out the energy and water totals for each material.</p> <p>energy totals polyester <math>97+33+340-33 = 437</math> MJ cotton <math>60+40+340-7 = 433</math> MJ</p> <p>water use totals polyester <math>17+1260+4900 = 6207</math> dm<sup>3</sup> cotton <math>22200+3900+4900 = 31000</math> dm<sup>3</sup>)</p> <p>Stronger candidates often added the negative energy values instead of subtracting them or wrote down their calculations with no indication of which figures applied to which material. Many weaker candidates wrote a meaningless jumble of figures. Few candidates mentioned sustainability in their answer, and many of those who did could not support their conclusion from the data. Stronger students generally gained a mark but few scored better.</p>
		<b>Total</b>	<b>5</b>	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
7	i MnO <sub>2</sub> (s) + 2C(s) → 2CO(g) + Mn(s) correct formulae and balancing ✓ state symbols ✓	2 (AO 2 × 1.2)	<p>ALLOW state symbol mark for any version of manganese oxide + carbon → carbon oxide + manganese</p> <p><b>Examiner's Comments</b></p> <p> <b>AfL</b> When asked to write an equation, candidates need to check that they know what type of equation they are asked for (ionic, balanced, word, half equation) and also whether they need to include state symbols. A relatively common shortcoming for this question was to omit either the balancing or the state symbols. In addition, candidates need to check the information given, a further misconception was to give CO<sub>2</sub> as a product. This error also shows that candidates have not taken time to self-correct their responses. The question stem instructs candidates that carbon monoxide is a product.</p> <p><b>Exemplar 2</b></p> <p><i>MnO<sub>2</sub> + 2C → Mn + 2CO</i> ✓ [2]</p> <p>Although this equation shows correct formulae and balancing [1] the candidate has missed the instruction to 'Include state symbols' leading to only one mark. A relatively common error was to miss this instruction and similarly to miss the significant figures and decimal places instructions in the mathematical questions.</p>

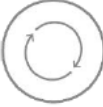
### Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					<p>Exemplar 3</p> <p><math>2Mn + MnO_2 \rightarrow MnO_2 + CO_2</math>..... [2]</p> <p>In this case there are two errors, both of which could have been 'self corrected' by the candidate has (s)he re-read the information given. The information states that manganese oxide is heated with carbon. It further states that carbon monoxide is formed. Neither carbon nor carbon monoxide is given in this equation. The instruction to 'include state symbols' has also been ignored. Therefore no marks could be credited.</p>
		ii	<p>Manganese is less reactive than carbon ORA ✓</p> <p>carbon reduces / removes oxygen from / donates electrons to manganese (oxide) ✓</p>	2 (AO 2 × 2.1)	<p><u>Examiner's Comments</u></p> <p>Almost all candidates knew that either carbon is more reactive than manganese or that manganese is reduced. This led to most candidates earning at least one mark.</p>
			<b>Total</b>	<b>4</b>	

## Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
8	a	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 marks)</b> States and explains differences in the information and fully discusses how the information supports PET bottles in terms of energy, emissions and waste.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b> States and explains a difference in the information and how the information supports PET bottles in terms of energy, emissions and waste.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p><b>Level 1 (1–2 marks)</b> States that the information supports the use of PET bottles. <b>OR</b> Uses the information to state a similarity or difference between the companies.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b> <i>No response or no response worthy of credit.</i></p>	6 (AO 3 × 3.1b) (AO 3 × 3.2a)	<p><b>AO3.2a</b> Analyses information and ideas to make judgements about information from both companies</p> <ul style="list-style-type: none"> <li>• both show that PET bottles use least energy</li> <li>• both show that PET bottles produce lowest mass/amount of waste</li> <li>• both show that PET bottles produce less (CO<sub>2</sub>) emissions</li> </ul> <p><b>AO3.1b</b> Analyses information and ideas to evaluate the differences from each company Company 2 information is about materials, not actual objects</p> <ul style="list-style-type: none"> <li>• Company 2 charts do not give volume of waste</li> <li>• measurements for company one are per 1000 litres of drinks and for company 2 it is over a year</li> <li>• company 2 includes paper</li> <li>• company 2 shows other materials all together / company one data is for individual materials</li> <li>• cannot be sure that values from company 1 give same percentages as company 2 / cannot check percentages</li> <li>• units used for mass are different</li> </ul> <p><b><u>Examiner's Comments</u></b></p> <p>In common with question 7, there are two parts to this Level of Response question. Firstly candidates need to state and explain which material should be chosen, then go on to identify any differences between the two companies. Most candidates used table 10.1 to identify PET as the 'best' material and usually justified this in terms of energy use, emissions and waste produced. The second part of the question proved more challenging. Some candidates omitted this entirely from their answer. Others gave very long answers to the first part of the problem and only gave a small reference at the end of their</p>

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			<p>answer, usually only identifying a single difference.</p>  <p><b>AfL</b> Candidates need to consider the information and instructions for Level of Response questions. It is wise to ensure that all aspects of the task are addressed, rather than giving a lot of time and writing space to one aspect at the expense of another. Candidates need to make sure that they answer all aspects rather than concentrate on one only. It is wise to go back and re-check the question before moving on.</p> <p><b>Exemplar 12</b></p> <p><i>Both comparisons show that PET (plastic) is the best option for making the containers. This is because it's the least likely to cause harm to the environment. On table 10.1 it shows how the PET bottle produces the lowest mass and volume of waste compared to the other option meaning less to potentially harm the environment. Also it emits the least amount of CO<sub>2</sub> all while using the least amount of energy. On Fig 10.1 it shows pretty much the same. The total mass of plastics is less than the CO<sub>2</sub> emissions produced, and the energy used is less than its opposition. Differences are that table 10.1 talk about emissions and mass in kg, while Fig 10.1 talk about them in tonnes. [6] Also table 10.1 is on about it in context to Total life cycle energy and waste per 1000 litres of drink while Fig 10.1 does it by 'per year'.</i></p> <p>This answer is succinct and clear. The candidate chooses PET as the 'best' material, justifies it and then gives two clear differences between the information. 6 marks.</p>



Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
				<p>Exemplar 13</p> <p>The PET bottle is the best, as it uses the lowest amount of energy – 4.1 GJ compared to 5.9GJ and 9.8GJ. It produces <del>less</del><sup>more</sup> than half the CO<sub>2</sub> than the aluminium can and over 4 times less than the glass bottle. It also produces the least amount of waste (4.8kg or 0.2m<sup>3</sup>). In Fig. 10.1 it is shown to have over half the energy consumption per year than paper, glass and aluminium.</p> <p>..... [6]</p> <p>This answer chooses PET and justifies the choice (Level 1, 2 marks). However, the second part of the task is completely omitted, so that Level 2 or higher cannot be earned.</p>
	b	Less litter / less waste / less transport of bottles / more are recycled ✓	1 (AO 1.1)	<p>IGNORE less harm to the environment alone</p> <p>IGNORE reused</p> <p><b>Examiner's Comments</b></p> <p>Many candidates stated either that more plastic bottles would be recycled or that the change would reduce in less individual transportation of bottles, both of which would impact positively on the life cycle assessment of the bottles. A well answered question.</p>
	c	non-biodegradable materials do not rot/break down/decompose / non-biodegradable materials cause a <u>long term</u> problem / take up space in landfill ✓	1 (AO 1.1)	<p><b>Examiner's Comments</b></p> <p>The best answers focussed on the idea of non-biodegradable materials and explained why people want to see these materials banned, due to the fact that they 'don't break down' or 'take up space in landfill'. Some answers did not reference any science in the answer, making statements about the companies such as 'they only want to make money'.</p>
		<b>Total</b>	<b>8</b>	