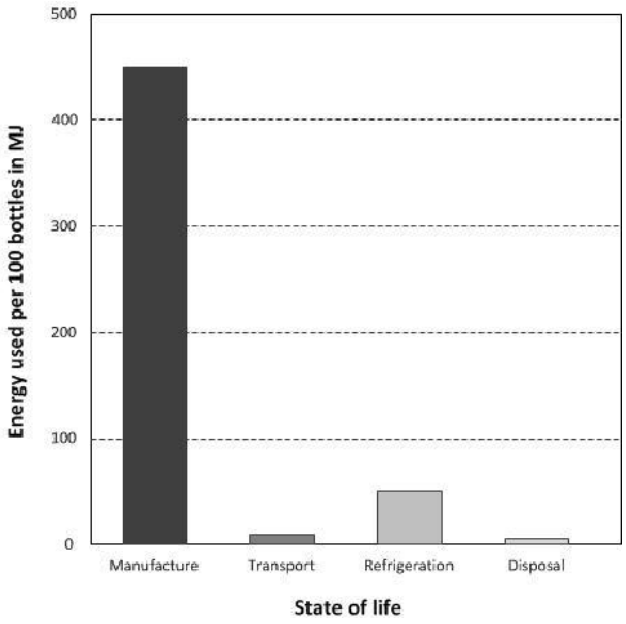
1(a). Disposable drink bottles are made from a polymer called PET.

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



Which statements about the data are true and which are false?

Put a tick (✓) in the correct column for each statement.

	True (✓)	False (✓)
Five times as much energy is used for refrigeration as disposal.		
The energy of manufacture is more than 10 times greater than for transport.		
Refrigeration uses less than 15% of the energy used for manufacture.		

(b). One way of using waste PET bottles is to burn them as fuel.

Burning 100 bottles gives out 120 MJ of energy.

Does this provide enough energy to manufacture 100 new bottles?

Use data from the graph to support your answer.

---

[2]

2(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.

---

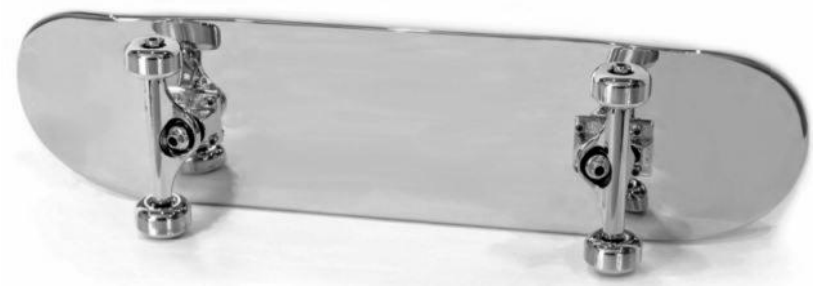
[1]

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

---

[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 ⟶ rust (hydrated iron(III)oxide)

Balance the symbol equation for the formation of rust.

……Fe(s) + $6H_2O(l)$ +…… $O_2(g)$ ⟶ 2 $Fe_2O_3.3H_2O(s)$

[2]

(b). Sam thinks that the rust itself is the problem.

Suggest, with an explanation, how Sam could solve the problem of the rusting ball bearings.

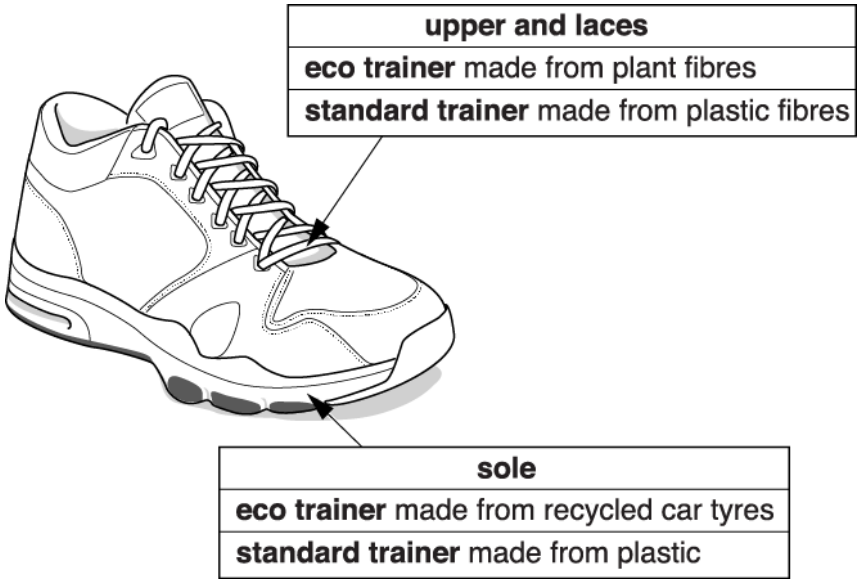
---

[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.

The table shows the data for the Life Cycle Assessment (LCA) of each type of trainer.



	Eco trainers		Standard trainers	
	Energy (MJ)	Greenhouse gases made (kg CO_2)	Energy (MJ)	Greenhouse gases made (kg CO_2)
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	_____	0.8	0.6
Total of the three stages	_____	1.7	11.0	8.5

(a)

(i) Complete the table above.

[2]

(ii) The company says that the eco trainers are less harmful to the environment and are more sustainable.

Are they correct?
Use data from the table to justify your answer.

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

[6]

5(a). The Life Cycle Assessment of a product can be divided intofour stages.

These stages are shown below, but are in the wrong order.

A using the product
B making the product from the material
C disposing of the product
D making the material from raw materials

Write the letters **A, B, C** and **D** for the fourprocesses in the correct order in the boxes.

[2]

(b). Scientists compare the environmental impact of three typesof disposable grocerybag.

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

They compare bags made of paper, biodegradable plastic andpolythene.

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

	Totals for 1000 bags for the whole LCA		
	paper	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_2)	80	180	40
Fresh water use (litres)	4520	4580	260

(i) Which type of bag uses the **most** energy?

---

[1]

(ii) Which type of bag gives the **least** greenhouse gas emissions?

---

[1]

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

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

---

[2]

(iv) There are other reasons for banning disposable bags made from polythene.

Which two statements, when taken together, give another reason?

Put ticks (?) in the boxes next to the **two** correct statements.

Polythene is a polymer.

Polythene bags may cause litter. ☐

Polythene is made by joining ethene molecules. ☐

Polythene bags are expensive. ☐

Polythene is transparent. ☐

Polythene takes a long time to decompose. ☐

[2]

(v) Plasticizers are added to polymers to make them more flexible.

Explain why the use of some plasticizers can have a bad environmental impact.

---

[2]

6(a). PVC is used to make window frames and bags for blood transfusions.

Life Cycle Assessments (LCA) for these two uses are different.

Which **two** statements about LCAs explain this difference?

Put ticks (✓) in the boxes next to the **two** correct answers.

Crude oil is used to make the PVC. ☐

Energy is used to make PVC from crude oil. ☐

There is an environmental impact when PVC is made from crude oil. ☐

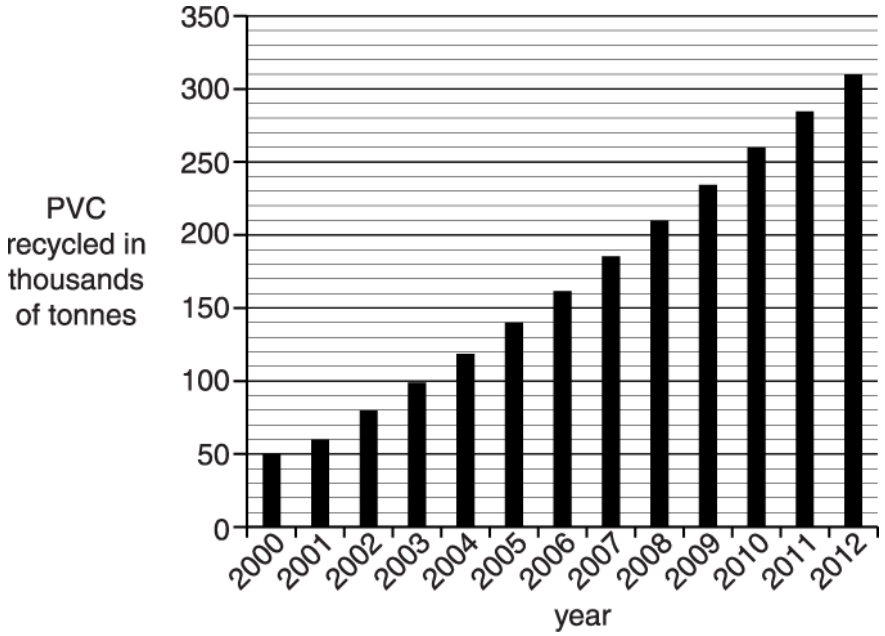
There is an environmental impact when each product is made from PVC. ☐

The length of time each product is in use. ☐

[2]

(b). PVC can be disposed of in landfill or recycled.

The graph shows the amount of PVC recycled in Europe since the year 2000.



(i) The European target was to recycle 200 000 more tonnes of PVC in 2010 than in 2000.

Was this target reached?

Explain your answer.

---

[2]

(ii) Suggest **two** advantages of recycling **more** PVC.

---

[2]

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

PET bottle

Aluminium can

Glass bottle

All three containers are non-biodegradable.

Many people want to choose containers that cause less harm to the environment.

Table 9.1 shows some information about the life cycle of the containers.

	Total life cycle energy and waste per 1000 litres of drink		
	Energy use (GJ)	Waste produced	
		Mass (kg)	Volume (m^3)
PET bottle	4.1	48	0.2
Aluminium can	5.9	120	0.3
Glass bottle	9.8	730	0.6

Table 9.1

Use the data from **Table 9.1** to explain why all of the containers cause some harm to the environment and decide which container causes the least harm.

---

[6]

(b). Table 9.1 does not include all of the factors needed to do a full life cycle assessment for the drinks containers.

Which **two** factors will have the biggest effect on the life cycle assessment of the drinks containers?

Tick (✓) two boxes.

The amount of sugar in each drink. ☐

The distances that the containers have to be transported. ☐

The design of the label on the container. ☐

The amount of water used to manufacture the containers. ☐

Whether the containers are used for fizzy or non-fizzy drinks. ☐

[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a		F T T ✓✓✓	3	
	b		(no because) the energy involved in manufacture is greater than 120 MJ ✓ energy involved in manufacture is more than 400 MJ / quotes a value 420–480 MJ ✓	2	
			Total	**5**	
2	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	
			Total	**3**	
3	a		**$4Fe(s)$✓ $+6H_2O(l) + 3O_2(g)$ ✓ → $2Fe_2O_3.3H_2O(s)$**	2	
	b		coat / galvanise / grease ball bearings ✓ to form barrier to keep the water and oxygen from the steel ✓ or use another material ✓ with the same desirable properties but that does not rust ✓ or suggestion of an alternative material such as ceramic ✓ and why ✓	2	Any two linked answers
			Total	**4**	
4		i	Total energy = 3.8;(1) CO_2 made disposing of trainers = 0.6;(1)	2	**Examiner's Comments** Most candidates could give the 2 correct values.

Question			Answer/Indicative content	Marks	Guidance
		ii	**[Level 3]** 'yes' and uses data from the table to correctly link less energy to sustainability **AND** less greenhouse gases (carbon dioxide) emitted to making the process less harmful. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) **[Level 2]** 'yes' and uses data from the table to identify less energy **and** less greenhouse gases (carbon dioxide) is emitted when producing eco trainers **OR** 'yes' and uses data from the table to correctly link less energy to sustainability **OR** less greenhouse gases (carbon dioxide) emitted to making the process less harmful. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **[Level 1]** Uses information from the diagram or use data from the table to support their answer Quality of written communication impedes communication of the science at this level. (1 – 2 marks) **[Level 0]** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	**This question is targeted at grades up to E** **Indicative scientific points may include:** **Use of data from the table** • eco trainers use less energy (3.8MJ energy vs 11.0MJ) compared to standard trainers. • eco trainers make less greenhouse gases (1.7g CO_2 vs 8.5g) compared to standard trainers. **Use of information from the diagram** • eco trainers are made from plant fibres • eco trainers are made from recycled car tyres **Sustainability** • Plants can be regrown • materials made from plant fibres are renewable • standard trainers use plastics from crude oil that is non-renewable • Less energy is used as less fossil fuels are used **Harmful to the environment** • Fewer greenhouse gases produced for eco trainers • Less impact on global warming from eco trainers. • Less energy is used as less fossil fuels are used so less pollution is made **Use the L1, L2, L3 annotations; do not use ticks.** **Ignore** direct harm to humans **Examiner's Comments** Although many candidates were able to correctly identify the reasons that the eco-trainers were better, successfully selecting the data to support their explanations, they

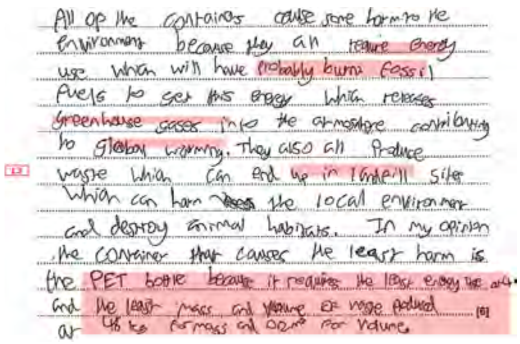
Question			Answer/Indicative content	Marks	Guidance
					did not then make the link between sustainability and harm to the environment. This meant a large number of level 2 responses. Unfortunately some candidates didn't 'use the data' from the rubric of the question and so were limited to level 1 by quoting information from the diagram.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
5	a		DBAC	2	4 correct scores 2 marks 3 or 2 correct scores 1 mark Examiner's Comments Candidates answered this question well, with many scoring 2 marks.
	b	i	paper	1	 Examiner's Comments Again candidates could select the appropriate data from the information given.
		ii	polythene	1	 Examiner's Comments Again candidates could select the appropriate data from the information given.
		iii	*any two from:* polythene uses least energy (1) polythene uses least fossil fuel (1) polythene produces least solid waste (1) polythene gives least greenhouse gases (1) polythene uses least water (1)	2	**allow** AW for less e.g. not as much / lower / low instead of least all answers must refer to categories in the table Examiner's Comments Most candidates gained two marks here but a significant number did not quote the properties from the table and just stated 'polythene bags had less of everything in the table'. The main problem was candidates answering without referring to any properties eg 'polythene is the lowest of everything'.

Question			Answer/Indicative content	Marks	Guidance
		iv	Polythene bags may cause litter. ✓ Polythene takes a long time to decompose. ✓	2	
		v	some plasticizers are toxic (1) they can leach out of plastic (1)	2	**allow** poisonous / harmful **ignore** causes health problems **allow** 'leak' as AW **Examiner's Comments** This question was poorly answered with candidates not being able to express the problems with plasticisers. They tended to write about problems with the environment and disposing of plastics that contain plasticisers or the effects on wildlife. Common responses for this question also dealtwith plasticizers inhibiting the biodegradability of plastics. Very few candidates mentioned anything about toxicity, and even fewer mentioned leaching.
			Total	10	

Question			Answer/Indicative content	Marks	Guidance
6	a		<table><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td>There is an environmental impact when the product is made from PVC.</td><td>✓</td></tr><tr><td>The length of time the product is in use.</td><td>✓</td></tr></table>	2	Examiner's Comments Most candidates scored 1 mark here, identifying that 'there is an environmental impact when each product is made from PVC'.
	b	i	Yes target was reached because: In 2000 – 50(thousand) tonnes PVC recycled and In 2010 – 260(thousand) tonnes recycled (1) Increase of 210 (thousand) tonnes (1)	2	**Accept** 10,000 tonnes above the target Examiner's Comments Many candidates did not read the values correctly from the graph. The total of PVC recycled was often incorrectly quoted as 250,000 or 300,000 rather than the correct response of 260,000 for 2010. The difference between the values in 2010 and 2000 was rarely quoted as 210,000.
		ii	**any two from** less to go in landfill; less crude oil used / saving resources; Less energy used / less fuel used in process; Fewer greenhouse gases released Process is (more) sustainable;	2	**Ignore** pollution **Accept** named greenhouse gases Examiner's Comments Many candidates identified that the waste would go to landfill if it was not recycled. Fewer candidates could give 'saving resources/energy' as a good reason or advantage for recycling.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
7	a		*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Chooses PET bottles and justifies their choice in terms of energy and waste using data from the table **AND** fully explains why all of the containers cause some harm to the environment. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Chooses PET bottles and justifies their choice in terms of energy and waste. **OR** Chooses PET bottles and uses data to explain why containers cause some harm to the environment. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Chooses PET bottles and makes a statement linked to energy or waste. OR Makes a statement about data linked to the harm to the environment. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	6 (AO 3 × 3.1b) (AO 3 × 3.2a)	**AO3.1b Links data for all containers to harm to the environment** • energy use uses fuels • energy use gives emissions / harmful gases • waste needs landfill/disposal • heavier waste linked to transport/energy use • higher volume takes up more space • glass bottle has highest mass and highest volume therefore takes up most space and harms the environment **AO3.2a Chooses and justifies PET bottles** • PET bottles use least energy • PET bottles produce lowest mass of waste • PET bottles produce lowest volume of waste • PET drinks bottles can be reused therefore using less energy than if they were recycled **ALLOW** biodegradable at level one, **ALLOW** discussion of sea pollution at Level one. Examiner's Comments Most candidates were able to identify the PET bottle as having the lowest score in each column. To achieve the highest level response, it was necessary to use the data explain how environmental harm would be caused by a large energy use (e.g. use of fossil fuels) or a large mass or volume of waste (transport or landfill). Lower ability candidates sometimes resorted to answering their own question by describing pollution by microplastics (as described in recent TV programmes).

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 2  All of the containers cause some harm to the environment because they all require energy use which will have probably burnt fossil fuels to get this energy which releases greenhouse gases into the atmosphere contributing to global warming. They also all produce waste which can end up in landfill sites which can harm the local environment and destroy animal habitats. In my opinion the container that causes the least harm is the PET bottle because it requires the least energy the 4.4 and the least mass and volume of waste produced at 46 kg for mass and 0.2 m³ for volume. [6] In this answer the candidate has identified that the production and disposal of all containers will cause harm to the environment. They talk about burning fossil fuels for the energy needs so producing greenhouse gases and the filling up of land fill sites with the waste. The candidate identifies PET as being the least harmful material to use and uses data from the table to justify their choice. This answer was credit a Level 3, 6 marks.
	b		The distances that the containers have to be transported ✓ The amount of water used to manufacture the containers✓	2 (AO 2× 2.1)	
			Total	8	