1. Ammonia is used to make fertilisers for agriculture.
Ammonia provides nitrogen compounds to make crops grow faster.

Which **two** other important elements do fertilisers provide?

Put rings around the **two** correct answers.

potassium sulfur phosphorus chlorine sodium

[2]

2(a). Jack says that this process is not sustainable in the long term.

Explain why Jack thinks this.

Use the information in the table to help you to explain your reasoning.

---[3]

(b). The equation for the process is:

methane + steam ⇌ hydrogen + carbon dioxide

$$CH_4 + 2H_2O \rightleftharpoons 4H_2 + CO_2$$

All of the methane is never used up in this reaction, there is always some left over.

(i) How does the equation show that the methane can never be all used up?

---[2]

(ii) The left over methane is recycled back into the start of the process.

Explain why this makes the process more sustainable.

---[2]

(c).

(i) Jack uses this equation to calculate the atom economy of the process.

$$\textbf{Atom economy} = \frac{\textbf{Total mass of hydrogen molecules made}}{\textbf{Total mass of molecules used}} \times 100\ \%$$

Equation: $CH_4 + 2H_2O \rightleftharpoons 4H_2 + CO_2$

Calculate the atom economy for this process.

atom economy = _____ % **[3]**

(ii) The information says that the atom economy is < 20 %.

Does the value you have calculated agree with this?

Explain your reasoning.

---**[2]**

3(a). A company makes chemical compounds and uses them to make products such as fertilisers and drugs.

The table gives information about these products.

Product	Type of process	Use
fertilisers	bulk	spread on soil to help crops grow
drugs	fine	used on people and animals

(i) What is the difference between the processes used to make bulk and fine chemicals?

---

[2]

(ii) Monitoring of purity is much more important for compounds used in drugs than for compounds used in fertilisers.

Use the information in the table to help you to explain why.

---

[2]

(iii) Each manufacturing process has many stages.

Chemists work in the stages that involve making the chemical compounds.

Which stages involve making the chemical compounds?

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

choosing feedstocks ☐

designing labels ☐

choosing the best reaction conditions ☐

deciding on how the products are advertised ☐

transporting the products ☐

[2]

(b). Millions of tonnes of hydrogen are made every year. In industry, most hydrogen is made by a reaction between methane gas and steam.

methane	+	steam	?	hydrogen	+	carbon dioxide
CH_4	+	$2H_2O$	?	$4H_2$	+	CO_2

The table shows some information about the process.

Feedstocks	methane (natural gas) and water
Number of stages in process	2
Temperature needed	700–1100 °C
Energy source	burning some of the methane gas
By-products	none
Waste product	carbon dioxide gas
Atom economy	15%

Use the information to help you to explain why this process is **not** sustainable.

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

---

[6]

(c). Scientists are working on a new process to produce hydrogen.

The new process splits water to make hydrogen. A catalyst is used in the process.

$$2H_2O \quad ? \quad 2H_2 \quad + \quad O_2$$

(i) What is the name of the by-product of this reaction?

---

[1]

(ii) Using a catalyst reduces the energy needed to break up the water.

How does the catalyst work?

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

The catalyst increases the time taken for the reaction. ☐

The catalyst lowers the activation energy. ☐

The catalyst provides a different route for the reaction ☐

The catalyst is used up instead of the water. ☐

[2]

4(a). The Haber process uses nitrogen and hydrogen to make ammonia for fertilisers.

The reaction between nitrogen and hydrogen is reversible.

Complete the equation for the process by drawing the symbol for a reversible reaction in the box.

$N_2 + 3H_2$ ☐ $2NH_3$

[1]

(b). The Haber process uses particular conditions to increase the rate of the reaction.

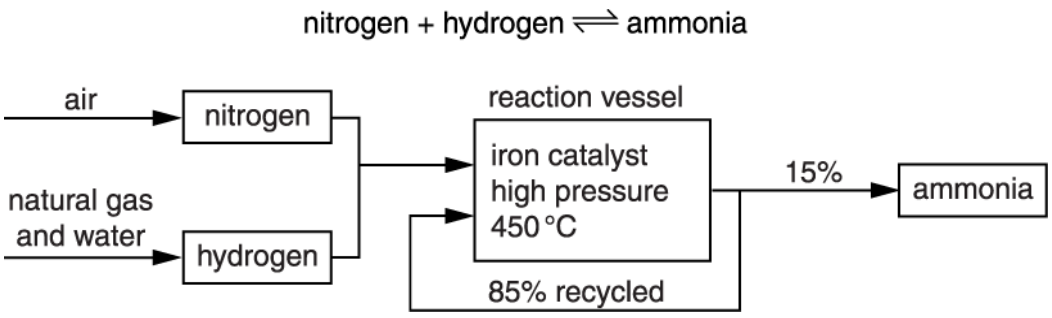
Which conditions increase the rate?

Put ticks (?) in the boxes next to the **three** correct answers.

high temperature	☐
using a catalyst	☐
recycling unreacted hydrogen and nitrogen	☐
high pressure	☐
using nitrogen from the air as a feedstock	☐

[2]

5(a). Ammonia, NH_3, is made by the Haber process.



The Haber process uses:

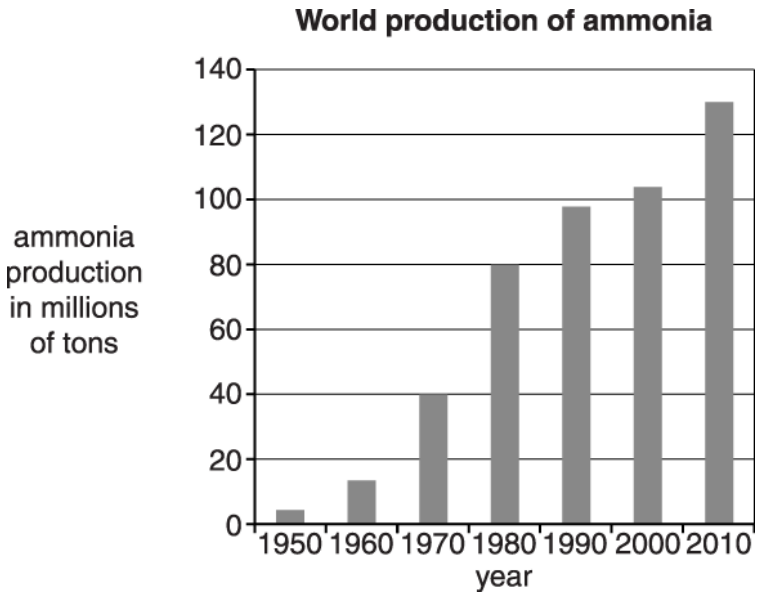
- a catalyst
- a temperature of 450°C
- a high pressure
- recycling of unreacted gases.

Explain how these help to make more ammonia.

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

[6]

(b). Look at the bar chart.



The main use of ammonia is to make fertilisers.

Large scale use of fertilisers made from ammonia causes environmental problems.

Write about these problems, and explain why they have got worse over the last 60 years.

[3]

6. The energy changes for reactions in industry are carefully controlled.
Why is this important?

Put ticks (?) in the boxes next to the **two** best answers.

Energy given out by reactions can be used to heat buildings.	☐
Reactions that give out energy use too much fuel to keep them hot.	☐
Energy changes in reactions affect the rate.	☐
Containers for reactions may be damaged by extreme temperatures.	☐
Reactions that take in energy need to be continuously cooled.	☐

[2]

7. When chemical engineers design an industrial process, they make it as sustainable as possible.
The industrial processes are more likely to be sustainable if:

- renewable chemicals are used
- there are few by-products.

Explain what **'renewable'** and **'by-products'** mean, and how they affect the sustainability of the process.

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

[6]

8(a). Large amounts of nitrogen gas in the air are turned into nitrogen compounds every year.
This is called 'fixing' the nitrogen.
It happens by different routes.

The table shows how much nitrogen is fixed every year by each route.

Route for fixing nitrogen	Amount of nitrogen fixed in million tonnes per year
burning fuels	20
making chemicals in industry	50
lightning in thunderstorms	10
growing crops on farms	90
trees growing	50
plankton in the sea	35

Which route fixes the most nitrogen in a year?

_____ [1]

(b). One of these routes is the Haber process for making ammonia.

Use the table to suggest how much nitrogen is fixed each year by the Haber process.

_____ million tonnes [1]

(c). In the Haber process, nitrogen and hydrogen react. Ammonia is the only substance made.

Write a word equation for this reaction.

_____ [1]

(d). The hydrogen needed for the Haber process is madein a separate reaction.

Which **two** substances are needed for this reaction?

Put a tick (✓) in the box next to the correct answer.

hydrogen and steam ☐

natural gas and steam ☐

nitrogen and steam ☐

water and steam ☐

[1]

(e). The UK makes 3000 tonnes of ammonia every day .
For every tonne of ammonia, 1.6 tonnes of carbon dioxide are made.
Half of this carbon dioxide can be captured.

How much carbon dioxide can be captured each day?

_____ tonnes **[2]**

(f). Most of the ammonia is used to make fertilisers.
Fertilisers are very useful, but can cause pollution.

Suggest why fertilisers are useful and how they might cause pollution.

---**[2]**

(g). The table shows some chemicals which are manufactured.

Chemicals such as ammonia are made on a large scale.

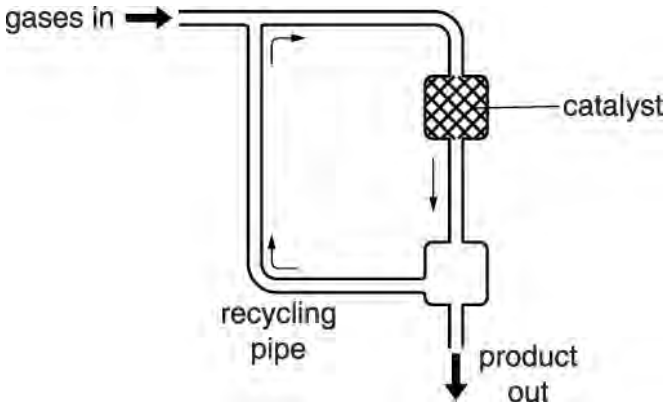
Some other chemicals are made on a small scale.

Put ticks (✓) in the boxes to complete the table.

Chemical	Large scale	Small scale
food additives		
phosphoric acid		
sodium hydroxide		
fragrances for perfumes		

[2]

9. In the Haber process, nitrogen and hydrogen react to make ammonia.



Write about the Haber process.

Your answer should include:

- what happens
- why it uses a catalyst
- why the gases are recycled.

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

[6]

10(a) Millions of tonnes of hydrogen are made every year.

.

The hydrogen is usually made from methane.

The process starts with methane and steam, and makes hydrogen and carbon dioxide.

In this process 52 tonnes of methane and steam make 8 tonnes of hydrogen.

(i) The waste product of this reaction is carbon dioxide.
What mass of carbon dioxide is made from 52 tonnes of methane and steam?

answer _____ tonnes **[1]**

(ii) Why does this suggest that the process is not very green?

---**[2]**

(b). A new process for making hydrogen is by heating wood from trees.
Both processes for making hydrogen make carbon dioxide.
Suggest why this new process might be greener than the old one.

---**[2]**

11(a). Some farmers use manure from cows as a natural fertiliser. Other farmers use ammonium sulfate as a synthetic fertiliser.

(i) The formula of ammonium sulfate is $(NH_4)_2SO_4$.

Which elements does ammonium sulfate contain?

Tick (✓) **four** boxes.

Ammonia	☐
Hydrogen	☐
Nitrogen	☐
Oxygen	☐
Sodium	☐
Sulfur	☐

[1]

(ii) Plants need one of the elements in ammonium sulfate to grow faster.

Write down the name of this element.

---

[1]

(b). Farmers can choose manure or ammonium sulfate as a fertiliser.

Farmers need to consider the cost of the fertiliser.

(i) Suggest **one** reason, **other than cost**, why some farmers use manure rather than ammonium sulfate as a fertiliser.

---

[1]

(ii) Suggest **one** reason, **other than cost**, why some farmers use ammonium sulfate rather than manure as a fertiliser.

---

[1]

12. Fizzy water can be found naturally.

The water is fizzy because it contains dissolved carbon dioxide gas. The carbon dioxide comes from the decomposition of rocks that contain carbonate compounds.

One compound found in rocks is magnesium carbonate.

Ali investigates the decomposition of magnesium carbonate by heating a small amount in a test tube. This is the equation for the reaction.

$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

Calculate the atom economy for the production of carbon dioxide in this reaction.

Use the formula: atom economy = $\frac{\text{mass of atoms in desired product}}{\text{total mass of atoms in reactants}} \times 100\ \%$

Give your answer to **1** decimal place.

Atom economy = ---------- % **[4]**

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			potassium ✓ phosphorus ✓	2	
			Total	2	
2	a		(links judgment to main reasons why non-sustainable) methane is non-renewable / finite / will run out / comes from fossil fuels ✓ carbon dioxide is a waste product which causes climate change ✓ makes another point 'against' the process: high temperature uses energy / large energy input / atom economy is low / large amount of waste products idea ✓	3	
	b	i	reversible reaction / explanation of reversible reaction ✓ idea that reaction never reaches 100% yield / all reactants do not react / reaction does not go to completion ✓	2	
		ii	does not waste raw materials / use less methane / methane is non-renewable ✓ less waste given out / less waste to dispose of ✓	2	
	c	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 15.38 (%) award 3 marks Total mass of H_2 molecules = 4 × 2 = 8 ✓ Total mass of molecules used = (2 × 18) + (1 × 16) = 52 ✓ atom economy = 8 ÷ 52 × 100 = 15.38 (%) ✓	3	ALLOW total mass of molecules used = (4 × 2) + 44 = 52 ALLOW 2 or more sig figs, correctly rounded.
		ii	idea that < means 'less than' ✓ (yes because) 15.38 is less than 20 ✓	2	ALLOW ECF on incorrect value from (d)(i)

Question			Answer/Indicative content	Marks	Guidance
			Total	12	

Question			Answer/Indicative content	Marks	Guidance
3	a	i	idea that bulk are made in large scale processes / made by a continuous process / idea of very large masses e.g. tonnes; (1) fine are made in small scale processes / made by batch processes / idea of smaller quantities e.g. kg; (1)	2	**Accept**: large amounts = bulk / small amounts = fine for (1) mark only **Accept** idea that bulk is much larger (clear comparison) for (2) **Examiner's Comments** Bulk and fine chemicals are a difficult area to address clearly. Although the manufacturing techniques are different (large scale and small scale) it is not correct to say that only small amounts of fine chemicals are used. Very large amounts of compounds such as paints, dyes and drugs are used every day, but each 'run' is on a small scale. Most candidates did know that the two types of chemicals are produced on a different scale, but some did not express this very clearly.
		ii	fertilisers are used on fields so not important that they are very pure / drugs are used on people or animals so must be very pure; impurities/drugs may be harmful / idea of health and safety issues;	any 2	**Accept** 'not safe' 'risk' 'cause harm' **Ignore** 'dangerous' 'it will kill you' 'side effects' **Ignore** references to fertilisers or bulk chemicals causing harm **Examiner's Comments** Most candidates extracted information from the table, such as the use of fine chemicals on people and animals, to gain one mark. Fewer linked this to the need to monitor purity for safety reasons or to reduce the risk of harm.
		iii	Choosing feedstock (Box 1); (1) Choosing the best reaction conditions (Box 3); (1)	2	**Examiner's Comments** Almost all candidates correctly identified at least one stage which involved making chemical compounds.
	b		**[Level 3]**	6	**This question is targeted at grades up to C** **Indicative scientific points may include:**

Question			Answer/Indicative content	Marks	Guidance
			Discusses the use of methane, energy and the reaction linked to sustainability. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Identifies aspects of the process that affect sustainability with clear links. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Makes a statement to link one aspect of the process to sustainability. 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)		Sustainability links about using methane • methane comes from a fossil fuel • methane is in finite supply/will run out / is non-renewable Sustainability links about energy • multi-stage processes use more energy • high temperature uses energy • high temperature uses fuel/methane • methane/fossil fuel is burned to heat process / provide energy Sustainability links about the reaction • waste product/CO_2 [accept CO_2 from burning methane/] causes climate change (**Ignore** pollutant/harms the environment) • atom economy low/ 'only' 15% **BOD** references to 'atom efficiency' but ignore 'efficiency' alone **Use the L1, L2, L3 annotations in RM Assessor; do not use ticks**. Examiner's Comments This level of response was shared with the higher tier paper. Most foundation tier candidates, as expected, gained marks in level 1. The main reasons for earning low marks were because candidates copied out the information in the table but did not add to the information to explain why the process is not sustainable. So, for example, stating 'the process produces carbon dioxide' was not enough to gain credit unless the answer added 'which causes climate change'. Candidates need to understand that 'explain' questions always ask them to add explanations to the data, not merely repeat it.

Question			Answer/Indicative content	Marks	Guidance
	c	i	oxygen (1)	1	Ignore O_2 **Examiner's Comments** The word 'by-product' did not seem to be well known. Less than half correctly identified oxygen as the by-product from the equation.
		ii	….lowers the activation energy (box 2); (1) … provides a different route (box 3); (1)	2	**Examiner's Comments** Most gained a single mark for identifying one or other of the two correct statements about catalysts.
			Total	**15**	
4	a		? ; (1)	1	Do not accept ? or ? **Examiner's Comments** Over half the candidates knew the correct symbol for a reversible reaction. Two complete arrows facing in opposite directions was the most common incorrect response.
	b		High temperature (box 1) Using a catalyst (box 2) High pressure (box 4)	2	All 3 correct = (2) 2 correct = (1) **Examiner's Comments** This question was well answered, almost all candidates knew which conditions increase the rate of reaction.
			Total	**3**	

Question			Answer/Indicative content	Marks	Guidance
5	a		**Level 3 (5–6 marks)** Answer gives a detailed description of how the conditions affect the reaction with some explanation of these effects. Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** Answer discusses how most of the conditions affect the reaction OR gives some explanation of how one of the conditions affects the reaction. Quality of written communication partly impedes communication of the science at this level. **Level 1 (1–2 marks)** Answer gives some indication of how the conditions affect the reaction. Quality of written communication impedes communication of the science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	**This question is targeted at grades up to E** **Indicative scientific points may include:** **effects** • catalyst is used to increase rate • high temperature increases rate • high pressure increases rate • recycling gases means reactants used again **explanations** • high rate of reaction makes more ammonia per unit time • catalyst lowers activation energy • high temperature / pressure increases collisions • high temperature makes particles move faster • unreacted gases are recycled so reactants are not wasted • it is a reversible / equilibrium reaction • increasing pressure increases yield / pushes equilibrium to right / make more ammonia **Use the L1, L2, L3 annotations in Scoris; do not use ticks**. **Examiner's Comments** This was the first of the six-mark extended-writing questions. There were some good descriptions of the effect of the various conditions on the amount of ammonia produced from the Haber process, with the effect on rate by catalysts and temperature appearing frequently. Stronger candidates were able to give reasons for the increases in rate by mentioning activation energy or collision rate. Some candidates failed to score by just restating the question or by describing the flow chart without reference to the effect of the conditions given.

Question			Answer/Indicative content	Marks	Guidance
	b		fertiliser is washed into rivers causing pollution / eutrophication (1) production of ammonia has increased / use of fertilisers has increased (1) **plus** a link from more ammonia / fertilisers to more pollution (1)	3	**allow** description of eutrophication **Examiner's Comments** There were some good descriptions of the environmental damage caused by large scale use of fertilisers but many candidates did not know what a fertiliser was leading to references to herbicides, air pollution, animals dying and damage to soil. There were also some good responses that used the bar chart to link the increase in ammonia production to an increase in use of fertilisers and hence greater environmental problems although many answers just discussed the need for more fertilisers to grow more food.
			Total	9	
6			energy changes in reactions affect the rate (1) containers for reactions may be damaged by extreme temperatures (1)	2	**Examiner's Comments** The majority of candidates achieved only one of the two marks. Many failed to select the option that containers may be damaged by high temperatures.
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
7			**Level 3** Explains both terms and discusses sustainability. *Quality of written communication does not impede communication of the science at this level.* (5 ? 6 marks) **Level 2** Explains both terms but not how they make the process sustainable, or explains one term and discusses sustainability. *Quality of written communication partly impedes communication of the science at this level.* (3 ? 4 marks) **Level 1** Makes a correct statement about 'renewable' or 'by-products' or sustainability *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 C** **Indicative scientific points may include:** **Sustainability** • resources available for future generations / long term future • environment not harmed in the long term / for the future • less waste linked to long term / future environment **Renewable:** • does not run out • can produce more • example ? eg plants regrow **Ignore** 'used again' 'made again' 'remade' 'recycled' **By-product:** • by-product ? unwanted product / waste product / another product • need for waste disposal • not all reactants utilised **Use the L1, L2, L3 annotations in Scoris; do not use ticks.** **Examiner's Comments** This level of response question had three aspects to the task. Candidates needed to discuss renewable, by-products and sustainability. To gain a level 3, candidates needed to address all three aspects. Commonly one was omitted. Most candidates knew and understood both what by-products are and that they can lead to a process being wasteful. The term 'renewable' was difficult for candidates to clearly explain. Explanations such as 'can be re-used' or 'can be re-made' or 'can be recycled' are not enough. Answers which gained credit included the idea of an unlimited supply, or a non-finite resource. Although many candidates used the word

Question			Answer/Indicative content	Marks	Guidance
					'sustainable' in their answer only the very best answers made it clear that this meant that the process could continue in the future indefinitely.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
8	a		growing crops on farms	1	**Examiner's Comments** Almost every candidate correctly interpreted the table to choose 'growing crops on farms' as the main route for fixing nitrogen.
	b		50 [million tonnes]	1	**Examiner's Comments** Almost every candidate correctly identified that 50 million tonnes of nitrogen are fixed by the Haber process annually.
	c		nitrogen + hydrogen ? ammonia or hydrogen + nitrogen ? ammonia	1	**Accept** $N_2 + 3H_2$?$2NH_3$ **Examiner's Comments** Most candidates correctly used the information to construct a fully correct word equation. Candidates need to read the information carefully to identify the reactants and products. Answers which did not score often had incorrect products, such as 'nitrogen hydroxide' or 'ammonia and water'.
	d		hydrogen and steam ☐ natural gas and steam ✓ nitrogen and steam ☐ water and steam ☐	1	**Examiner's Comments** Most knew that natural gas and steam are the source of hydrogen for the Haber process.
	e		2400 (2) 1.6 x 3000 (1)	2	**Examiner's Comments** Most candidates gained at least partial credit. Some did not divide by two, implying that they had not read all of the information. Some who were unsure how to do the calculation showed good technique by trying different ways of multiplying and dividing the numbers until they reached a plausible number.

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>f</td><td></td><td>Advantage: (crops or plants) faster growth / more growth / more yield / (1)

Pollution: go into water / fertilisers contain nitrates / leaching / idea of eutrophication / energy to make fertilisers (1)</td><td>2</td><td>Accept ‘growth’ alone

Ignore ‘pollution’ unless more detailed
Ignore direct cause of air pollution

Examiner's Comments

Some very good answers were seen which discussed both rate of crop production and eutrophication. There were two aspects to this question, how fertilisers are useful and how they cause pollution. A common reason for a partial score was to only address one of the aspects.</td></tr>
<tr><td></td><td>g</td><td></td><td><table><tr><th>chemical</th><th>large scale</th><th>small scale</th></tr><tr><td>food additives</td><td></td><td>✓</td></tr><tr><td>phosphoric acid</td><td>✓</td><td></td></tr><tr><td>sodium hydroxide</td><td>✓</td><td></td></tr><tr><td>fragrances for perfumes</td><td></td><td>✓</td></tr></table></td><td>2</td><td>4 rows correct = 2
3 or 2 rows correct = 1

Examiner's Comments

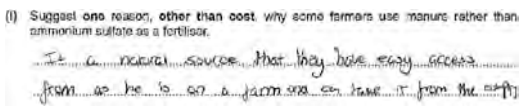
Although some knew which chemicals were made on a large and small scale, some gave all of the answers the wrong way round. This may be because candidates think that food additives and fragrances are common products and so must be made on a larger scale than the two named bulk chemicals.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>10</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
9			**[Level 3]** Discusses why the catalyst is used AND why the gases are recycled AND what happens; must include indicative points from all three categories. Quality of written communication does not impede communication of the science atthis level. (5 – 6 marks) **[Level 2]** Includes indicative points from two of the three categories OR an indicative point from each of the three categories. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **[Level 1]** Includes some indicative points. 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 mayinclude: **What happens:** • Nitrogen comes from air • Hydrogen comes from methane • Gases go to a reaction vessel • Which contains a catalyst • Catalyst is not used up • The catalyst is iron • Cooling turns ammonia gas to liquid • (Liquid) ammonia is removed from the system • Unreacted gases are recycled • (The forward reaction) is exothermic • Conditions are a compromise / are not optimum • The pressure used is 200 atm / high pressure used • The temperature is 450°C / high temperature **Why it uses a catalyst:** • to speed up the reaction / make ammonia more quickly • Catalyst lowers activation energy • Catalyst provides an alternative route for reaction **Why the gases are recycled:** • Reaction is reversible / reaches equilibrium • Not all the chemicals react • Recycling is more cost-effective / improves efficiency • Reduces waste / more sustainable / improved atom economy / increases yield Accept annotations to the diagram in lieu of text. Use the L1, L2, L3 annotations in Scoris;

Question			Answer/Indicative content	Marks	Guidance
					do not use ticks. Examiner's Comments This question was answered extremely well by many candidates. Marks were achieved by almost all students attempting the question. Centres had taught the principles of the Haber Process in many instances, successfully, to a higher level. Responses given were well structured and clearly explained. Candidates had been careful to try and address all three aspects of the question. Their responses were detailed and included many key scientific terms. The term “catalyst” was explained well; often discussing the lowering of activation energy, or the provision of an alternative route for the reaction. The reasons for recycling of gases was often clearly depicted including reducing waste, and having a high atom economy. Furthermore, the details given about the process were exact; temperatures and pressures were stated, and it was common for candidates to have remembered that the catalyst was iron. The difference between four marks and six marks was usuallybecause candidates had not mentioned a reduction in waste, or that some gases are re-used because they did not react in the first pass through the converter.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
10	a	i	44 [tonnes]	1	**Examiner's Comments** Answered correctly by many candidates; the principle of conservation of mass had been taught well in centres, and candidates recognised how to arrive at the correct response of 44 tonnes.
		ii	One from waste, and one from effect **Waste:** Most of reactants form a product which is not useful / a lot of waste / carbon dioxide (gas) is made / process has a low / poor atom economy (1) **Effect:** Product is a greenhouse gas / causes global warming / Product causes air / atmospheric pollution (1)	2	**Examiner's Comments** Many candidates achieved at least one mark here – usually for recognising that alot of waste was produced by the reaction, and many were able to state that carbon dioxide is a greenhouse gas. Some candidates did not achieve full marks because they stated that the reaction makes carbon dioxide (already given in the stem).
	b		Discusses both production and intake of CO_2: When trees are burned the CO_2 is released, however, this CO_2 was taken in by trees for photosynthesis = 2 marks Carbon neutral / attempts a description of carbon dioxide being given out being used by trees (1)	2	If no other mark is achieved then allow 1 mark for: wood is renewable / you can grow more trees ORA **Examiner's Comments** This question posed challenges for the majority of candidates. Two marks were rarely achieved. Despite the question stating that *both* processes produced carbon dioxide, candidates still used this as a response. This question required candidates to discuss both the intake and production of carbon dioxide; trees absorb carbon dioxide was sometimes given as a response, but candidates also needed to explain that this offsets the carbon dioxide produced in combustion.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
11	a	i	Hydrogen, nitrogen, oxygen, sulfur ✓	1 (AO 1.1)	Any other boxes ticked are CON Examiner's Comments This question discriminated well, with many candidates gaining credit.
		ii	Nitrogen ✓	1 (AO 1.1)	Examiner's Comments More able candidates chose nitrogen, with the main incorrect choice being oxygen. This latter, whilst incorrect, struck examiners as an indication that less able candidates were thinking through the alternatives carefully.

Question			Answer/Indicative content	Marks	Guidance
	b	i	Any one from: artificial fertilisers (can) cause environmental damage ✓ uses a waste product ✓	1 (AO 3.2a)	IGNORE 'environmentally friendly' /soil damage ALLOW animals produce it / there are animals on the farm <u>Examiner's Comments</u> Examiners got the sense that, in this question, scientific thinking had been swamped by popular attitudes. Candidates of all abilities suggested that manure was used because ammonium nitrate contained either 'chemicals' or 'artificial chemicals'. Others suggested that manure is preferable because it is 'natural'. A minority of candidates gave more considered responses, including one excellent answer which discussed the ethics of public perception. Exemplar 1  (i) Suggest **one** reason, **other than cost**, why some farmers use manure rather than ammonium sulfate as a fertiliser. It a natural source that they have easy access from as he is on a farm so can have it from the earth This answer was credited one mark for reference to using a resource/waste product that is produced by another part of the farm.
		ii	Any one from: not enough manure/cows AW ✓ supply of natural fertilisers is difficult to manage/transport / AW ✓ composition of natural fertilisers is variable / AW ✓	1 (AO 3.2a)	IGNORE 'more effective' unless explained ALLOW easier to use / can be used in smaller amounts / AW ✓ 'quicker' BOD 'more reliable' – not enough detail <u>Examiner's Comments</u> Many candidates were able to make reasonable suggestions for the use of ammonium sulfate.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
12			FIRST CHECK ANSWER ON ANSWER LINE **If answer = 52.2 /52.4 / 52.3 (%) award 4 marks** (formula mass of reactants or $MgCO_3$) = 84.3/84 ✓ (formula mass of product or CO_2) = 44 ✓ Correct substitution = 44/84.3 x 100 / 44/84 x 100 ✓ Ans+dec pl= 52.2 / 52.4 / 52.3 (%) (1 decimal place) ✓	4 **(AO 2.2 × 3)** **(AO 1.2)**	If no marks awarded for MP3 and MP4 **ALLOW** correct working towards formula masses for max (2) 24(.3) + 12 + (3x16) / 12 + (2 x 16) **ALLOW** ecf **ALLOW** 52.1(%) (Rounding assessed in previous question) <u>Examiner's Comments</u> Many candidates gained some credit for their working, successfully calculating the relative molar masses of magnesium carbonate and of carbon dioxide, even if performing the division proved a lot more taxing.
			Total	**4**	